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For The Hon^ble
John Forbes Esq^r.

From the Translator

THE Figure of the Earth, Determined from OBSERVATIONS Made by ORDER of the FRENCH KING, AT THE *POLAR CIRCLE*:

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AND

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Tranſlated from the *French* of M. *de Maupertuis*.

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* Read in the Publick Meeting of the *Royal Academy of Sciences,* the 16th of *April,* N. S. 1738.

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The AUTHOR's

PREFACE.

THE great Attention of the Public to what ſhall be decided in the Queſtion concerning the Figure of the Earth, has not permitted me to delay printing this Treatiſe till it ſhould appear in the courſe of our annual *Memoirs*. As I intend to place the Whole of our Operation in the cleareſt Light that's poſſible, that every one may judge of its Accuracy, I have ſet down the Obſervations themſelves, juſt as they ſtood in the Regiſters of Meſſrs. *Clairaut*, *Camus*, *le Monnier*, *Outhier*,

thier, and my own, which all agreed with each other; without making the *Corrections* usual in Works of this nature. Whose Authors, suppressing their Observations, have thought it sufficient to give the Triangles *corrected*, and their Angles *reduced* to the just Sum of 180 Degrees; with the *Mean* of their Observations of the Amplitude of the Arc they measured. But the Method I have used will, I conceive, be the most satisfying to my Readers; as it enables them, from the Agreement or Differences of the Observations, to see how far they reach or fall short of the Accuracy required. They may too, if they please, make Calculations of their own in a different Manner, and compare the Result with ours.

HERE it may not be improper to ſay ſomething of the Uſefulneſs of this Undertaking; which includes likewiſe the Voyage to *Peru*, begun before ours, and not yet finiſhed.

IT is well known of what different Opinions the Learned have been theſe 50 Years paſt, with relation to the Figure of the Earth; ſome holding it to be that of a *Spheroid* flatted towards the Poles; others that it is a Spheroid prominent in that Direction. This Queſtion, for its Curioſity only, might well merit the Conſideration of Philoſophers and Mathematicians: But the Advantages ariſing from the Diſcovery of the Earth's true Figure, go beyond mere Speculation; they are real, and of very great Importance.

WERE the Poſition of Places with reſpect to Longitude and Latitude ever ſo exactly marked on our Globes and Charts, it would ſignify little to the finding their true Diſtances, while we were ignorant of the length of the Degrees of the *Meridian* and of the *Parallels* to the *Equator*. And if the diſtances of Places are not very well known, to what dangers muſt the Ships be expoſed that are bound for them!

WHILE the Earth paſs'd for perfectly Spherical, it was enough to find the exact Length of any one Degree of a Meridian; this would give all the reſt: And the Degrees of the *Parallels* might be deduced by an eaſy Computation. Princes and Philoſophers had in all Ages been making Attempts this way. But the

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Meaſures of the Ancients were ſo inconſiſtent with one another, as to differ ſometimes by more than one half. And if to this we add the Uncertainty we are in as to the exact Length of their *Stadia* and *Miles*, we ſhall find that what they have left us upon this Subject is very little to be depended upon. In later times, Surveys were made, free indeed of the Inconvenience laſt mentioned, but which ſerved to almoſt as little purpoſe as thoſe of the Ancients. *Fernel*, *Snellius* and *Riccioli* have ſeverally given us the Length of a Degree of the *Meridian* ; but when you compare them with each other, you will find Differences that riſe to 8000 Toiſes *Paris* Meaſure ; that is, to about the ſeventh part of a Degree. And tho' *Fernel* happened to come neareſt the Truth, as

this could not be known, nor even presumed from the Method in which he went to work, his Meaſure was as uſeleſs as the reſt.

WE muſt not however omit mentioning a *Survey* that was made in *England* in the Year 1635, becauſe it appears to have been done with great Care, and with proper Inſtruments. Mr. *Norwood* having in two different Years taken the Sun's Altitude at the Summer Solſtice at *London* and at *York*, with a Sextant of five foot Radius, found the difference of Latitude of theſe two Cities to be 2°. 28′. He then meaſured their Diſtance, and having taken into the Account all the turnings of the Road, with the Aſcents and Deſcents, reduced it to an Arc of the Meridian containing 9149 Chains. This compared with the Difference of Lati-

tude

tude gave him 3709 Chains to a Degree; that is, 367196 feet *English*, or 57300 of our Toises.

AN Order of LOUIS XIV. to the *Academy of Sciences*, soon produced a Work far surpassing whatever had been done of this kind. M. *Picard*, upon a Base exactly measured, and by a very few Triangles, determined the Length of the Arc of the Meridian between *Malvoisine* and *Amiens* to be 78850 Toises: He observed, with a Sector of 10 foot Radius, that bore a Telescope of the same length, the difference of Latitude of these two Places, *viz.* 1°. 22'. 55". And from thence concluded a Degree to contain 57060 Toises.

THE Method that Mr. *Picard* had uſed, with the many Precautions he had taken, were ſufficient Vouchers for his exactneſs. And the KING reſolved that the whole Arc of the Meridian through *France* ſhould be meaſured in the ſame manner. This Work Mr. *Caſſini* finiſhed in the Year 1718. He had divided the Meridian of *France* into two Arcs, which he meaſured ſeparately. The one from *Paris* to *Collioure* had given him 57097 Toiſes to a Degree; the other from *Paris* to *Dunkirk*, 56960; and the whole Arc from *Dunkirk* to *Collioure*, 57060; the ſame as Mr. *Picard*'s.

AT laſt Mr. *Muſſchenbroek*, jealous of the Glory of his Nation, to which himſelf ſo much contributes, having reſolved to correct the Errors of

of *Snellius*, both from his own Obſervations and from *Snellius* himſelf, found the Degree between *Alcmaer* and *Berg-op-ſom* to contain 29514 Perches, 2 foot, 3 inches *Rhinland* Meaſure, which he ſays is equal to 57033 Toiſes, 0 feet, 8 inches of *Paris*.

THESE laſt Surveys agreed ſo much better with each other than the former, that for the Climates they were made, we needed no better; nor indeed to find the Circumference of the whole Earth, provided it were Spherical, and had all its Degrees equal.

BUT why ſhould the Earth be a Sphere? In an Age when nothing leſs than the utmoſt Preciſion in all Science is inſiſted on, it was not to be

ſuppoſed

ſuppoſed that the Proofs the Ancients had given of its ſpherical Form could paſs. Even the Reaſonings of the moſt celebrated Mathematicians, who gave it the Figure of a flat Spheroid, were not thought entirely ſatisfying; becauſe they ſeemed ſtill to be connected with ſome Hypotheſes, although theſe Hypotheſes were ſuch as one cannot well help admitting. As for the Obſervations made in *France*, they were as little thought ſufficient to give the Earth the Figure of a long Spheroid.

AT laſt the KING order'd the length of a Degree to be meaſured at the Equator and at the polar Circle, that the Compariſon of one of theſe Degrees with that in *France* might decide whether the Earth was long or flat; and that at the ſame time

time their Comparifon with each other might determine the Earth's Figure in the exacteft manner.

IT is evident in general, that Sir *Ifaac Newton*'s Figure of a flat Spheroid, and Mr. *Caffini*'s of a long one, will give very different Diftances of Places that have the fame Longitude and Latitude. And it is of fome confequence to Navigators, not to fancy they are failing upon one of thefe Spheroids, while they are really failing upon the other. The Miftake would not be fo confiderable, if the Ship's Courfe lay all in the fame Meridian. But for Places under the fame Parallel, the difference of the Diftances upon the one or the other Figure would be very great. In a Courfe of 100 Degrees Longitude, there might be a Miftake of more than

than two Degrees, if ſailing really upon Sir *Iſaac Newton*'s Earth, one ſhould imagine himſelf to be upon Mr. *Caſſini*'s. And how many Ships have periſhed by ſmaller Miſtakes?

THERE is this Conſideration further; That, till the Figure of the Earth is determined, there is no knowing how far theſe Errors may go. And in fact it appears from our Meaſures that ſuch a Miſtake will be ſtill greater than, from Sir *Iſaac*'s Table, it could be known to be.

I ſay nothing of the Miſtakes that muſt happen in oblique Courſes. It is needleſs to make any Eſtimate of them at preſent: Only it is plain enough that they would be ſo much the greater as the Courſe approached to a Paralleliſm with the Equator.

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THE Errors juſt now mentioned merit certainly our ſerious Attention: And if the Sailors are not at preſent ſenſible how advantageous it would be for them to know the true Figure of the Earth, it is owing rather to the Imperfection than to the Perfection of their Art. They are ſubject to a great many other Miſtakes in the Direction of their Courſe, their Diſtance run, and the like; amidſt which the Error ariſing from their Ignorance of the Earth's Figure lies confounded and hid. Yet it is ſtill a Source of Error more: And if ever (as it is to be hoped) the other Elements of Navigation are brought to Perfection, it will be ſeen of what Uſe the exact Determination of the Earth's Figure is.

THIS Determination would likewife be exceedingly ufeful in that important Problem, *To find the Parallax of the Moon*; which would greatly contribute to the compleating a Theory of this Satellite of our Earth; upon which the beft Aftronomers have always moft reckoned for the difcovery of the Longitudes at Sea.

AND to come to other Objects, lower indeed, but not the lefs ufeful, one may affirm that the Perfection of *Levelling* depends upon the Knowledge of the Earth's Figure. Such is the Chain that connects the Sciences, that the fame Principles which ferve to direct a Ship in her Courfe, and to trace the Moon in her Orbit, ferve likewife to bring Water into a Fountain or Canal.

'TWAS,

'TWAS, no doubt, upon theſe Conſiderations that the KING order'd the two Voyages to *Peru* and to the *Polar Circle.* Near Views of particular Advantage have ſometimes produced great Enterprizes for the diſcovery of Countries, or of Paſſages to abridge certain Voyages; but the Determination of the Figure of the Earth is a general Benefit to all Nations and Ages.

THE Magnificence of every thing that regarded this Enterprize was equal to the Greatneſs of the Deſign. To the four Academicians, the Count de *Maurepas* added the Abbé *Outhier*, whoſe Capacity to aſſiſt in this Work was well known; He gave us Mr. *de Sommereux* for our Secretary, and Mr. *d' Herbelot* for

for *Designer*. If so many Hands were necessary for executing a Work of such difficulty and in such a Country, our Number would at the same time render our Operations the more authentic. And that nothing might be wanting in either of these respects, the KING consented that M. *Celsius*, Professor of Astronomy at *Upsal*, should join us. Thus we left *France*, furnished with all that could be thought necessary to ensure Success; and the Court of *Sweden* gave such Orders, as procured us in its remotest Provinces all the Assistance imaginable. The Count of *Casteia* then Ambassador in *Sweden*, sollicited the Recommendations of that Court, with that Zeal he always shows in the KING's Service; and if we have done any thing for the Sciences, that deserves Acknowledgment, they will

pay

pay it to that Miniſter, to whoſe goodneſs we are ſo much indebted.

I thought it might not be diſagreeable to my Readers to prefix a ſhort Hiſtory of our Labours, which was read in the laſt publick Meeting of the Academy; and of which I have retrenched only ſome Reflections, that the detail of our Operations has now render'd ſuperfluous.

THE reſt of the Work is divided into three Books; becauſe it treats of very different Matters.

IN the firſt you have the whole Proceſs of our Operations for meaſuring an Arc of the Meridian that cuts the Polar Circle, and for aſſuring ourſelves that our Meaſures were juſt. It is divided into two Parts,

 the

the one containing our firſt Operations; the ſecond the Repetition of theſe Operations, with Verifications of the Whole.

OUR ſcrupulous Exactneſs not only in the Calculations, but in the detail of all the Circumſtances of our Obſervations, may to ſome People ſeem to need an Apology. But in a Subject that has been ſo much diſputed, and is of ſuch importance, we thought we could not carry our Exactneſs too great a length. Mr. *Clairaut*, whoſe Skill in much more difficult Calculations is well known, was of great ſervice to us in theſe.

THE firſt Book concludes with a Problem which I had already publiſhed in the *Memoirs of the Academy* 1735, and which I have here inſerted,

ſerted, becauſe this is its proper place. It ſerves to determine the Magnitude and Figure of the Earth from the lengths of two Degrees of a Meridian; and by it, one may eaſily make a Table of the lengths of a Degree for every Latitude.

THE ſecond Book contains ſeveral Obſervations by which we determined the Elevation of the Pole at *Torneå* and *Kittis*; the quantity of the Refraction at the Polar Circle, and the Longitude of *Torneå*. We at the ſame time detect a received Error, which might not a little affect both Aſtronomy and Geography.

IN the Year 1695 *Charles* XI. King of *Sweden*, having ſent Meſſrs. *Spole* and *Bilberg* to *Torneå* to make ſome Aſtronomical Obſervations;

theſe two Mathematicians, with ſmall and imperfect Inſtruments, obſerved ſeveral Altitudes of the Sun at the Summer Solſtice, from which they concluded the Elevation of the Pole at *Torneå* to be 65°. 43′; while if they had employed the proper *Data* they ſhould have found it to be but 65°. 40′. even by their own Obſervations. Having thus determined the Elevation of the Pole, their Obſervations of the Sun's North Meridian Altitude gave them the Refractions at *Torneå* almoſt double to what they are in *France*.

IN all this there was a great deal of Error: The Town of *Torneå* is 11′ more to the North than they made it; And the Refractions are not there different from what they are at *Paris*.

FROM

FROM a great Number of Obſervations we found the Elevation of the Pole at *Torneå* to be 65°. 50′. 50″. And we have ſome reaſon to think there are few Towns in the moſt inhabited parts of *Europe*, whoſe Latitude is more exactly known. We have there oftner than once obſerved, at ſhort intervals of Time, and even in the ſame Day, the two Altitudes of the Pole-Star, which is there ſo elevated, that though one knew not the Refractions, or made no account of them, they are ſo inconſiderable that the obſerved Altitude might afterwards be ſafely uſed in meaſuring the Horizontal Refractions.

ON the other hand, in this Climate the Sun's Meridian Altitudes

in the Horizon furniſh many curious Obſervations upon the Subject of Refraction.

WE had likewiſe the Planet *Venus* for about two Months conſtantly above the Horizon, and could take her Meridian Altitudes both to the South and North.

AND from all theſe Obſervations made with the greateſt Care, we found that the Refraction at *Torneå* differed not from that in *France*: any difference we found was no more than what might ariſe from the Obſervations themſelves, or from Accidents wherewith the Refractions upon the Horizon may be affected.

IF then the Refractions are found to be confiderably lefs at the Equator than at *Paris*, and that they really increafe from the Equator towards the Pole: This at leaft is certain, that from *Paris* to the Polar Circle that Increafe is imperceptible. And the Account which the *Hollanders* that wintered in *Nova Zembla* give of the Sun's appearing much fooner upon the Horizon than he ought to have done in that Latitude, cannot fhake what we had confirmed to us by fo great a Number of Obfervations.

AS to the Longitude, *Jupiter*'s Situation in the Southern Signs kept him always hid in the Horizontal Vapours, at the times when we might have obferved him. But we made

ſome other Obſervations to this purpoſe. One was of a Lunar Eclipſe in the Horizon; the reſt of Occultations of fix'd Stars by the Moon; from which we concluded with tolerable Certainty, that the difference between the Meridians of *Paris* and *Torneå* is $1^h. 23'$.

THESE Obſervations are chiefly owing to the Vigilance of Mr. *le Monnier* and Mr. *Celſius*; who in a Climate, where the Heavens are ſo coy to Obſervation, were continually attentive to ſeize every favourable Moment.

THE laſt Book contains our Experiments upon the Force of Gravitation in the Frigid Zone: A Subject which, beſides its general Importance

tance in Natural Philoſophy, is ſo cloſely connected with the Figure of the Earth, that Sir *Iſaac Newton* and Mr. *Huygens* thought, that from the different Weight of Bodies alone the Earth's Figure might be determined, and even more exactly than by an actual Menſuration of the Degrees. Upon the diſcovery of the Increaſe of Gravitation towards the Poles, they concluded, that to preſerve the ballance of the Parts that compoſe this Globe, and that the Seas might not overflow the Parts towards the Equator, the Earth muſt there riſe higher, and fall in towards the Poles. From the Increaſe of Gravitation as we found it at the Polar Circle, this Falling in muſt be ſtill greater than Sir *Iſaac* has made it. And ſome Experiments of our Academicians at

the

the Equator, which are lately come to our hands, confirm the ſame Thing.

I conclude the Whole with a Problem ; To find the Direction of the primitive Gravity, or the Angles it makes with that of actual Gravitation ; which was the more proper in this place, as it comprehends the Reſult of all our Obſervations, both for the actual Menſuration of the Earth, and upon the Increaſe of Gravitation, and as from it may be deduced particular Solutions of a great many curious and uſeful Queſtions upon theſe two Subjects ; which are neceſſarily complicated with each other.

I have added a Map of all our Mountains and the Country adjoining; but the Poſition of thoſe Mountains only on which we made our Obſervations, is determined geometrically.

A

DISCOURSE

READ IN THE

PUBLICK MEETING

OF THE

Royal Academy of SCIENCES,

The 13th of *November*, N. S. 1737,

Upon the Meaſure of a Degree of the Meridian at the Polar Circle.

THE Motives and Purpoſe of our Journey to the North, I laid before this Aſſembly eighteen months ago: at preſent I am to give an account of its Execution, which it may not be improper to introduce by ſhortly reſuming what firſt gave riſe to this Undertaking.

IN

IN the Year 1672, M. *Richer* having obſerved, that at the Iſland of *Cayenne*, in the Neighbourhood of the Equator, Bodies weighed leſs than in *France*; this Diſcovery, with the ſeveral Conſequences that muſt follow from it, drew the attention of the Learned; and an illuſtrious Member of this Academy found that it equally proved the Motion of the Earth round its Axis, which did not much want any new Proof, and the Falling in of the Earth towards the Poles, which was then a Paradox. M. *Huygens* applying his new invented Theory of Centrifugal Forces to the Parts that compoſe the Terraqueous Globe, ſhewed, that if we conſider theſe parts as gravitating uniformly towards a Centre, and at the ſame time, revolving round an Axis, they muſt, to preſerve their mutual Ballance, take the Form of a *Spheroid flatted* towards the Poles. He went ſo far as even to determine the quantity of this *Flatneſs*; and all this from the common Principles of Gravitation.

SIR *Iſaac Newton* ſetting out from a different Theory, that of the univerſal Attraction of Matter, arrived however at the ſame

Concluſion with M. *Huygens*; only the quantity of this *Flatneſs* came out different in Sir *Iſaac*'s Calculation. In ſhort, one may venture to ſay, that if we examine the Figure of the Earth by the Laws of *Statics*, all the different Theories lead to the ſame Concluſion; whereas the Figure of an *oblong* or *oval Spheroid* cannot reſult but from *Hypotheſes* of *Gravitation* that are extremely forced and unnatural.

UPON the Eſtabliſhment of the *Academy of Sciences*, one of their firſt Reſearches had been, the juſt meaſure of a degree of the Terreſtrial Meridian. And this M. *Picard* had executed, for the Climate of *Paris*, with all the Exactneſs that could be deſired. But this Meaſure could be univerſally true, only upon the Suppoſition of the Earth's being perfectly ſpherical. If it was a flat Spheroid, it muſt be too great for the Degrees towards the Equator, and too little for thoſe towards the Pole.

THE whole Arc of the Meridian that paſſes through *France* was afterwards actually meaſured. But to our great ſurprize, the

the Degrees to the Northward came out ſhorter than the more Southerly, quite the reverſe of what was to be expected from the Figure aſſigned by Meſſ[rs]. *Huygens* and *Newton.* According to this laſt Survey, the Earth muſt be prominent towards the Poles; and other Operations made upon the *Parallel* that paſſes through *France*, which ſeemed to be of great weight, confirmed the ſame thing.

THUS was the Academy divided in their Sentiments, and perplexed even by their own Enquiries, when the KING thought fit to ſignify his pleaſure, that the Queſtion ſhould be finally decided. A Queſtion not vainly ſpeculative, and fit only to exerciſe the idle and fruitleſs Subtilty of Philoſophers, but which might have a real influence upon *Aſtronomy* and *Navigation.*

TO give a proper Solution, it was neceſſary to compare two degrees of the Meridian, the moſt different in Latitude that was poſſible. For if theſe degrees increaſe or decreaſe from the Equator to the Pole, the ſmall difference between two neighbouring degrees, might mix itſelf with the Errors com-

committed in *Obſerving:* whereas if the degrees that are compared, lie at a greater diſtance from each other, this difference being repeated as often as there are intermediate degrees, muſt riſe to a Sum too conſiderable to eſcape Obſervation.

THE *Count de Maurepas*, a Lover and Patron of Learning, and who aims always at rendring it ſubſervient to the Good of the State, found the advantage of *Navigation* and that of the *Academy* equally concerned in this Undertaking. And the ſame view of publick Utility engaged the attention of the Cardinal *de Fleury*, whoſe Protection and Favour the Sciences enjoyed in the midſt of a War, in a higher degree than they durſt have hoped for in the moſt profound Peace. To the great joy of the Academy, an Order is preſently diſpatched from Court to determine the Controverſy concerning the Figure of the Earth; and, a certain number of its Members are immediately deputed to put it in execution.—So many were to go to meaſure the firſt Degree of the Meridian at the Equator; Theſe ſet out a whole Year before us. The reſt were commiſſioned Northward, to

meaſure the remoteſt Degree they could reach. And the ſame Alacrity, the ſame Zeal to ſerve their Country appeared in thoſe that were to endure the Rage of Equator Suns, and thoſe that were to freeze beneath the Polar Circle.

THE Company deſtined for the North was compoſed of four Academicians, Meſſ[rs] *Clairaut*, *Camus*, *le Monnier*, and *Myſelf*; the *Abbé Outhier*, and M. *Celſius* the celebrated Profeſſor of Aſtronomy at *Upſal*, who aſſiſted at all our Operations, and whoſe Abilities and Advice were of ſingular uſe to us. If I might be allowed to do juſtice to the Courage and Talents of the reſt of my Companions, it would appear that the Work we were engaged in, difficult as it was, muſt become eaſy in ſuch Company and with ſuch Aſſiſtance.

THE Gentlemen that ſailed for the Equator we have no accounts of this great while paſt. Scarcely know we any thing more of them, than the difficulties they have had to ſtruggle with: and our own Experience has taught us to fear the worſt. For us, we have been more fortunate; and are ſafe

returned to present to the *Academy* the fruit of our Labours.

NO sooner was the Vessel that carried us over arrived at *Stockholm*, than we resolved without loss of time to set out for the Bottom of the Gulph of *Bothnia*, where we might judge which side of the Gulph was the most proper for our Operations, better than we could do by trusting to our *Charts*. Nothing could retard us, neither the frightful Stories they told us at *Stockholm*, nor the Goodness of his *Swedish Majesty*; who, notwithstanding the Orders he had given in our behalf, told us oftner than once, that it was not without a sensible Concern he saw us pursue so desperate an Undertaking. We arrived at *Torneå* time enough to see the Sun perform his Course for several days together without setting: a Sight that strikes with wonder an Inhabitant of the Temperate Zones, even though he knows it is what must necessarily happen in that Climate.

HERE it may not be amiss to give some Idea of our intended Work, and the Operations we had to go through, to measure a Degree of the Meridian.

EVERY body knows that as one advances towards the North, the Stars about the Equator appear lower, and thoſe towards the Pole more elevated. And 'tis probably this Appearance that gave the firſt Indication of the Earth's Roundneſs. This difference of the Altitudes of the ſame Star ſeen from the Extremities of an Arc of the Terreſtrial Meridian, I call the *Amplitude* of that Arc. This *Amplitude* is the Meaſure of the Curvature of the Arc; or, as it is commonly expreſt, it is the number of Minutes and Seconds that Arc contains.

IF the Earth was perfectly ſpherical, the Amplitude, or difference of the Meridional Altitudes of the ſame Star, would be always proportional to the length of its correſpondent Arc in the Terreſtrial Meridian. Thus, if, in the Climate of *Paris*, a diſtance of 57000 Toiſes upon the Terreſtrial Meridian anſwered to an *Amplitude* of one degree, at *Torneå*, to produce the ſame difference of Meridional Altitude, an equal diſtance of 57000 Toiſes muſt be gone over in the Meridian.

IF

IF, on the contrary, the Surface of the Earth was a perfect Plane, how far soever one travelled Northward, the Meridional Altitudes of the Stars would suffer no change.

IF therefore the Surface of the Earth has, in different Climates, different degrees of Curvature; that is, if it approaches more or less to a perfect Plane, the Portions of the Terrestrial Meridian, that, in different Climates, answer to the same Amplitude, must be of different Lengths. If the Earth is flatted towards the Poles, a Degree of the Terrestrial Meridian will be longer towards the Poles than towards the Equator. And by the comparison of distant Portions of the Terrestrial Meridian that answer to a Degree, the Figure of the Earth may be determined.

HENCE it is clear, that to find the Length of a degree of the Terrestrial Meridian, a certain Distance must be actually measured upon it, and the different Altitudes of the same Star must be taken at the two Extremities of that Distance, in order to compare the Length of the Arc with its Amplitude.

OUR firſt Work then was to meaſure ſome conſiderable Diſtance in the Meridian; and for that purpoſe to form a Series of Triangles connected with a Baſe, whoſe Length we could take by an actual Survey.

WE had all along flattered ourſelves that we might perform our Operations upon the Coaſts of the Gulph of *Bothnia*. The convenience of tranſporting ourſelves and our Inſtruments to the different Stations, by Sea, with the many advantageous Points of View which the Iſlands, as they are marked in all the Charts, ſeemed to promiſe us, had turned our Thoughts altogether upon theſe Coaſts and Iſlands. But when we had gone with great impatience to view them, all our labour ſerved only to convince us, that our firſt Deſign was impracticable. Theſe Iſlands, which line the Coaſts of the Gulph, and the Coaſts themſelves, which we had fancied to be ſo many Promontories, that might furniſh us with diſtant Points of View from one to another, lay all of them ſo low upon the Surface of the Water, that at a ſmall diſtance, the Convexity of the Earth muſt ariſe between them and us. Near the Coaſt they

even

even covered one another from our sight: Nor did they advance far enough into the Sea to afford us the Direction we wanted. So that after several small Voyages in pursuance of our first Design of making use of these Islands, we were at last obliged to give it up.

I had set out from *Stockholm* to *Torneå* in a Coach, with the rest of the Company: but about the middle of this long Journey, having accidentally fallen in with the Vessel that carried our Instruments and Servants, I had gone on board and was got to *Torneå*, some days before my Companions. At my landing, I had found the Governour of the Province just setting out to visit North *Lapland*, which was of his Department; and had seized the occasion of his Company, to get some notion of the Country till my Friends should come up. I had advanced 15 Leagues to the North, passed the Night of the Solstice upon *Avasaxa*, one of the highest Mountains in the Country, and had got back to *Torneå* by the time my Companions arrived. In this Excursion, which took up three Days, I had observed that the River of *Torneå*, as far as I had traced it, followed

pretty nearly the Direction of the Meridian, and that there were high Mountains on every ſide that might furniſh very diſtant Points of View.

HENCE we took the hint of performing our Operations upon the tops of theſe Mountains, to the Northward of *Torneå*; but the thing appeared next to impoſſible.

IN the Deſarts of a Country ſcarcely habitable, in that immenſe Foreſt which extends from *Torneå* to *Cape Nord*, we muſt go through Operations that are not eaſy even where no Convenience is wanting. To penetrate into theſe Deſarts, there were but two ways, both of which we muſt prove; one, the ſailing upon a River full of Cataracts; the other, croſſing thick Woods and deep Marſhes on foot. And if we ſhould be able to make our way into the Country, after the moſt painful Marches, we muſt have to clamber up ſteep Rocks, and clear the tops of Mountains of the Wood that intercepted our Sight. We muſt in theſe Deſarts put up with the moſt wretched Diet, expoſed to the Flies, which in this Seaſon are ſo inſufferable as to drive the *Laplanders* and

and their Rain-Deer from their Habitations to ſeek ſhelter on the Coaſts of the Ocean. In fine, we muſt undertake this Work without knowing, or being able to inform our ſelves, whether it was at all practicable; whether the want of one Mountain might not, after all our Toils, abſolutely interrupt the Series of our Triangles; or whether it would be poſſible to find upon the River, a *Baſe* with which they could be connected. If none of theſe Obſtacles proved inſurmountable, ſtill there remained the Labour of building *Obſervatories* upon the moſt Northerly of the Mountains, the carrying thither as numerous a Collection of Inſtruments as is perhaps to be ſeen in *Europe*, and there making the niceſt Obſervations of Aſtronomy.

THESE were Obſtacles ſufficient to alarm us; yet on the other hand our Views were too charming to be parted with. Beſides the Pleaſure of conquering ſo many Difficulties, we ſhould have ſurveyed a Portion of the Earth, the remoteſt that is perhaps within the reach of Mortals; the Degree of the Meridian that cuts the *Polar Circle*, and lies partly within the *frozen Zone*.

Then,

Then, as we had deſpaired of making any uſe of the Iſlands in the Gulph, this was really the only Reſſource that remained. For to go down again to the more Southerly Provinces of *Sweden*, was a Thought we could not bear.

July, 1736. WE ſet out then from *Torneå* on *Friday* the 6th of *July*, with a Company of *Finland* Soldiers, and a good number of Boats laden with Inſtruments, and ſuch Proviſions as were thought moſt neceſſary.

WE began our Journey by ſailing up the great River, that riſing in the inmoſt Parts of *Lapland*, purſues its courſe till it falls into the Gulph of *Bothnia*, having firſt divided itſelf into two Branches that form the Iſle of *Swentzar*, where is built a Town of the ſame Name in the Latitude of 65°. 51′. From this day forward, our only Habitation was the Deſarts, and the Summits of thoſe Mountains which we were to connect by our Triangles.

AFTER a Voyage of twelve hours, we landed about Nine in the Evening at *Korpikyla*, a Hamlet by the River-ſide, inhabited by

by *Finlanders.* And having travelled acroſs the Foreſt on foot for ſome time, we arrived at the Bottom of a ſteep Mountain called *Niwa*, whoſe Summit, a bare Rock, we choſe for our firſt Station. Upon the River we had been tormented by great Flies with green Heads, that fetch blood whereever they fix. But on the top of *Niwa* we had to deal with ſeveral other kinds ſtill more intolerable. By good luck we found two *Lapland* Girls tending a ſmall Herd of Rain-Deer, but almoſt quite hid in the Smoke of a great Fire they had kindled: And upon enquiry being told it was in this manner they defended themſelves from the Flies, we immediately had recourſe to the ſame Method. *July.*

THE 8th of *July*, at One in the Morning, Mr. *Camus* and I left our Company upon *Niwa*, to go and reconnoitre the Mountains to the Northward. We travelled up the River, to a high Mountain called *Avaſaxa*, where having cleared its top of the Trees, we order'd a *Signal* to be built. Our Signals were hollow Cones, compoſed of a great many large Trees ſtript of the Bark. By this means they were white enough to

be

July. be viſible at the diſtance of 10 or 12 Leagues. And we had taken the precaution to cut Marks upon the Rocks, and drive Stakes into the Ground, covering them with large Stones, that, in caſe of any Accident, we could eaſily recover the Centre of our Cone. In ſhort, our Signals were as convenient for Obſervation, and as ſolid as moſt Edifices in the Country.

AS ſoon as this was finiſhed, we came down from *Avaſaxa*, and embarking on the little River of *Tengliö*, which falls into the great River at the foot of this Mountain, we directed our Courſe upwards to a place the neareſt we could find to a Mountain that ſeemed to ſuit our purpoſe. And from thence a March of three Hours over a Moraſs, brought us to the foot of *Horrilakero*. Though extremely fatigued, we got to the top of it, and paſſed the Night in cutting down the Wood that covered it. Moſt part of this Mountain is a reddiſh Stone, interſperſed with a ſort of white Cryſtal, of an oblong Form, and laid parallel-wiſe. Here the Flies, more mercileſs than thoſe of *Niwa*, were not to be driven off by Smoke. We were obliged, notwithſtanding the exceſſive

Heats,

Heats, to wrap our Heads in our *Lappmudes*, *July.*
(a ſort of Gown made of Rain-Deer Skins) and to cover us over with Branches of Firr, and even whole Trees; which rather ſtifled us, than defended us from theſe troubleſome Animals.

HAVING cut down all the Wood on the top of *Horrilakero*, and built a Signal, we returned by the ſame road, to find our Boats that we had drawn up upon the Bank, the People of this Country being but ill provided of Cordage to ſecure them in the ordinary way. 'Tis indeed no hard matter to drag along, or even carry the Veſſels that are uſed in the Rivers of *Lapland.* A few thin Firr-boards compoſe the whole Veſſel, ſo extremely light and flexible, that the continual beating, with all the force of the Stream, againſt the Stones which theſe Rivers are full of, does it no manner of harm. 'Tis terrible to thoſe that are not accuſtomed to it, and aſtoniſhing even to thoſe that are, to ſee one of theſe weak Machines drive down a Cataract, in a Torrent of Foam and Stones, ſometimes raiſed aloft in the Air, and next moment loſt in the Deep. A bold *Finlander* ſteers it with a long Oar, while

July. while his two Companions row hard to ſave it from the purſuing Wave that threatens every moment to overwhelm it. Then may you ſee the whole Keel by turns raiſed above Water, and leaning only with its one Extremity on the top of a yielding Billow. As theſe *Finlanders* have ſo much Courage and Addreſs in paſſing the Cataracts, their Art and Care in the management of their Boats upon other Occaſions is no leſs remarkable. A Tree, Branches and all, ſerves them ordinarily for both Sail and Maſt.

WE embarked again on the *Tengliô*, which brought us down into the River of *Torneå* on our return to *Korpikyla.* Four Leagues from *Avaſaxa* we left our Boats, and after an hour's march over the Foreſt, gained the foot of *Cuitaperi*, a ſteep Mountain, its Summit a Rock covered with Moſs, and affording an extenſive Proſpect all round; which, to the South, takes in the Gulph of *Bothnia:* Here we erected a Signal, whence we could diſcover *Horrilakero*, *Avaſaxa*, *Torneå*, *Niwa* and *Kakama*; and then continued our Courſe down the River. Between *Cuitaperi* and *Korpikyla* we found ſome frightful Cataracts,

racts, where the *Finlanders* always set their *July.* Passengers ashore. But our excessive fatigue had made it more supportable to risque passing them in the Boat, than to walk but an hundred Yards. At last, on the Evening of the 11th, we joined our Friends whom we had left on the top of *Niwa:* They had descryed our Signals, but, by reason of the continual Fogs, had not been able to make any Observations.

WHETHER it is the Sun's long Stay above the Horizon, that raises more Vapour than the Night can condense, I shall not determine. This is certain, that, during the two Months we past on these Mountains, the Sky was never clear till a northerly Wind rose to carry off the Fogs. This disposition of the Air detained us sometimes 8 or 10 Days upon one Mountain, waiting for a favourable Moment, when we might have a distinct View of the Objects we wanted to observe. Next Day after our return to *Niwa* we took some Angles, and the Day following, by the favour of a cold north Wind, we were able to finish our Observations.

THE

July. THE 14th we left *Niwa*, and while Meſſ^rs *Camus*, *le Monnier* and *Celſius*, went to *Kakama*, Meſſ^rs *Clairaut*, *Outhier* and myſelf, took the Road of *Cuitaperi*, whence the Abbé *Outhier* went the 16th to plant a Signal at *Pullingi*. The 18th we made our Obſervations, which, notwithſtanding ſome Interruption from the Thunder and Rain, were compleated that ſame Evening. The 20th we ſet out all together, and by Midnight arrived at *Avaſaxa*.

THIS Mountain is ſituated on the bank of the River 15 Leagues from *Torneå*. Its Aſcent is difficult, lying through a Wood that reaches half way up, is then interrupted by a heap of ſteep ſlippery Rocks, and afterwards continued to the very top of the Mountain, at leaſt before we cut down ſo much of it as was neceſſary to open our Proſpect. The north-eaſt ſide is a moſt frightful rocky Precipice, where the Falcons build their Neſts. At the foot of it runs the *Tengliö*, encircling *Avaſaxa* before it falls into the River of *Torneå*. From its Summit the Proſpect is the moſt beautiful that can be imagined; to the South quite un-

unbounded, and diſcovering the courſe of the River to a vaſt extent. Towards the Eaſt one can trace the *Tengliö* in its paſſage through ſeveral Lakes. And on the North, at a diſtance of 12 or 15 Leagues, the View is terminated by a prodigious Number of Hills, heaped one upon another, as we uſe to repreſent the *Chaos*, and amongſt which it might not be eaſy, after one had got thither, to diſtinguiſh the one he had pitch'd upon at *Avaſaxa*. *July.*

WE ſpent 10 Days upon this Mountain, during which, Curioſity procured us frequent Viſits from the Inhabitants. They brought us Fiſh and Sheep, and ſuch bad Fruits as their Woods produce.

BETWEEN this Mountain and *Cuitaperi*, the River is exceeding broad, forming a ſort of Lake; which, beſides its extent, was very conveniently ſituated for our *Baſe*. Meſſ^rs *Clairaut* and *Camus* undertook to determine its direction, and ſtayed for that purpoſe at *Öfwer-Torneå*, after we had finiſhed our Obſervations at *Avaſaxa*: While I, with Meſſ^rs *le Monnier*, *Outhier* and *Celſius*, ſhould go up to *Pullingi*. The day

July. we left *Avaſaxa* we croſſed the *Polar Circle*; and on the Morrow, the 31ſt of *July*, by Three in the Morning arrived at *Turtula*, a ſort of Hamlet where they were cutting their little crop of Barley and Hay. After having travelled ſome time in the Wood, we embarked on a Lake which brought us to the foot of *Pullingi*.

THIS is the higheſt of all our Mountains, and of an exceeding difficult Acceſs; as well on account of its Steepneſs, as the depth of the Moſs wherein we had to fix our Steps: We reached the top however at ſix in the Morning. Our Stay here from the 31ſt of *July* to the 6th of *Auguſt* was no leſs diſagreeable than the Aſcent had been painful. We had to fell a whole Wood of the largeſt Trees. And the Flies attacked us with ſuch Fury, that our Soldiers of the Regiment of *Weſtro-Bothnia*, a Body diſtinguiſhed even in *Sweden*, where there are ſo many brave Troops; theſe Men, hardened with the greateſt Fatigues, were obliged to wrap up their Faces, or cover them with Tarr. Theſe Inſects poiſoned our Victuals too; no ſooner was a Diſh ſerved, but it was quite covered over with them, while another

another ſwarm, with all the rapaciouſneſs of Birds of prey, was fluttering round to carry off ſome pieces of a Sheep that was a dreſſing for us. *July.*

THE Morrow after our arrival at *Pullingi*, the Abbé *Outhier* went with an Officer of the Regiment of *Weſtro-Bothnia*, to whoſe good Offices we are very much indebted, to build a Signal towards *Pello*; and the 4th we diſcovered another which the ſame Gentleman had erected upon *Niemi*. Having taken the Angles between theſe *Signals*, we left *Pullingi* the 6th of *Auguſt* to go to *Pello*, where, after having forced our way up four Cataracts, we arrived the ſame day. *Auguſt.*

PELLO is a Village inhabited by a few *Finlanders*: In its Neighbourhood is *Kittis*, where was one of our Signals; the loweſt of all our Mountains. As we were going up we diſcovered a copious Spring of pure Water, that iſſues from a fine gravel, and reſiſts the keeneſt Froſt. For when we returned to *Pello* about the end of Winter, while the Sea at the bottom of the Gulph, and all the Rivers were frozen as hard

August. as Marble, we found this Spring running as in Summer. We had the good fortune to make our Obſervations ſoon after our arrival, ſo that we were obliged to ſtay at *Kittis* but till next day. We ſet out from thence at three o' clock in the Afternoon, and came the ſame Evening to *Turtula*.

FOR a Month paſt we had been Inhabitants of the Deſarts, or rather of the Mountains tops; the Earth or Rocks, ſpread with the Skin of a Rain-Deer, had been our Beds, and our Food chiefly Fiſhes that the *Finlanders* brought us, or which ourſelves had catch'd, with ſome ſort of Berries or wild Fruits that grew in the Woods. This way of living did by no means agree with Mr. *le Monnier*. His Health had been ſenſibly upon the Decline, eſpecially from the hardſhips we had ſuffered upon *Pullingi*, and being now quite gone, I was obliged to leave him at *Turtula* to go down the River, and try to recover it at the Curate of *Öſwer-Torneå*'s Houſe, which was the beſt, and almoſt the only place of Shelter in the Country.

I left *Turtula* at the ſame time in company with Meſſ^rs^ *Outhier* and *Celſius*, to go

go across the Forest and find out the Signal which the Officer had erected at *Niemi*. And a frightful Journey it was. We set out from *Turtula* on foot till we got to a Brook, where we embarked on three little Boats. But they passed with such difficulty between the Stones, that we had to go out of them at every turn, and leap from one Rock to another. The Brook brought us to a Lake so full of little yellowish Grains, of the bigness of Millet, that the whole Water was discoloured with them. I took them to be the *Chrysalis* of some Insect, and was tempted to fancy that this Insect must be some kind of those Flies that so tormented us; for I could think of no other Species of Animals whose Numbers corresponded to the quantity of Grains that covered this large Body of Water. From the Extremity of this Lake we had to walk to another of very clear Water. Here we found a Boat, and putting our Quadrant on board, resolved to follow it along the side of the Lake on foot. But the Wood was so thick, that we were forced to cut our way through it, and were entangled at every step by the depth of the Moss and the fallen Firr-trees that lay across our Road. In all these Woods *August.*

August. there are almoſt as many fallen Trees as ſtanding. The Soil, after it has reared them to a certain height, can no longer furniſh the proper Nouriſhment, nor is it deep enough to allow them to take firm root. The leaſt blaſt of Wind overſets them, and in all theſe Woods one ſees nothing but Firrs and Birches rooted out in this manner. The wood of the latter, Time reduces to Duſt without at all affecting the bark; and one is ſurprized to find pretty large Trees that crumble upon the ſlighteſt touch. This has probably given the hint of the uſe the *Swedes* make of it, to cover their Houſes; and indeed there could be nothing imagined fitter for the purpoſe. In ſome Provinces they cover the Bark with Earth, which forms upon the Roof a ſort of Garden, ſuch as are to be ſeen upon the Houſes of *Upſal.* In *Weſtro-Bothnia*, the Bark is bound with Firr-Poles, fixt a-top, and hanging down on either ſide of the Roof. Our Woods then had rather the Aſpect of the Ruins of Woods whoſe Trees have moſt of them periſhed: And it was thro' one of theſe, one of the moſt horrid of them too, that we muſt paſs, with the twelve Soldiers that carried our Baggage. Having at length reach'd a third

Lake very large, and the fineſt Water that *Auguſt.* can be imagined, we put our Inſtruments and Baggage on board two Boats we found there, and waited their return upon the Coaſt. The high Winds, and bad Condition of theſe Boats rendred their Paſſage tedious. Yet they came back at laſt, and ferry'd us over to the foot of *Niemi* by Three o' Clock in the Afternoon.

THE beautiful Lakes that ſurround this Mountain, and the many difficulties we had to overcome in getting thither, gave it the Air of an enchanted Iſland in a Romance. And indeed any where but in *Lapland* it would be a moſt delightful place. On one hand you ſee a grove of Trees riſe from a Plain, ſmooth and level as the Walks of a Garden, and at ſuch eaſy diſtances as neither to embarraſs the Walks, nor the Proſpect of the Lake that waſhes the foot of the Mountain. On the other you have Appartments of different Sizes, that ſeem artificially cut in the Rock, and to want only a Roof to compleat them. And the Rocks themſelves ſo perpendicular, ſo high and ſo ſmooth that you would take them for the Walls of an unfiniſhed Palace rather than for the work

August. of Nature. From this height we had Occasion ſeveral times to ſee theſe Vapours riſe from the Lake, which the People of the Country call *Haltios*, and which they deem to be the guardian Spirits of the Mountains. We had been frighted with Stories of Bears that haunted this place, but ſaw none. It ſeemed rather a place of reſort for *Fairies* and *Genii* than for Bears.

THE Day after our Arrival, the Fog hindered our Obſervations. The 10th we ſuffered ſome Interruption from the Thunder and Rain, but the Day following we had them compleated, left *Niemi*, repaſſed our three Lakes, and were got back to *Turtula* by Nine in the Evening. We parted from *Turtula* on the 12th, and at three in the Afternoon joined our Friends at the Curate's of *Öfwer-Torneå*, where leaving Mr. *le Monnier* and the Abbé *Outhier*, I ſet out the 13th with Meſſrs *Clairaut*, *Camus* and *Celſius* for *Horrilakero*. We entred the *Tengliö* with four Boats. Its Cataracts are troubleſome, rather for the little Water there is, and the great number of Stones, than for the rapidity of its Stream. As we ſailed along I was ſurprized to ſee, upon the banks of

of this River, Roſes of as lively a red as any *Auguſt.* that are in our Gardens. About Nine at Night we reached *Horrilakero*, but our Obſervations were not finiſhed before the 17th. The 18th we returned to *Öſwer-Torneå*, where our whole Company was now aſſembled.

THE moſt convenient place for our *Baſe* had been already pitched upon. Meſſ[rs] *Clairaut* and *Camus*, after having carefully viewed the banks of the River, had determined its Direction, and fixed its Length by Signals raiſed at either Extremity.

HAVING gone up to *Avaſaxa* in the Evening to take the Angles which muſt connect this *Baſe* with our *Triangles*, we ſaw *Horrilakero* all in flames. It is an Accident not uncommon in theſe Woods, where there is no living in the Summer time without Smoke, and where the Moſs and Firrs are ſo combuſtible, that a Fire once kindled will ſpread over ſome thouſands of Acres. Theſe Fires, or their Smoke, have ſometimes retarded our Obſervations as much as the thickneſs of the Air. As this burning of *Horrilakero* had been no doubt occaſioned by our not taking ſufficient care

to

August. to extinguiſh our Fires, we diſpatched 30 Men to cut off its Communication with the neighbouring Woods. But on the 21ſt, after we had finiſhed our Obſervations at *Avaſaxa*, *Horrilakero* was ſtill burning; we ſaw it involved in a Cloud of Smoke, and the Fire that had made its way downwards was ravaging all the Foreſt below.

SOME of the People that were ſent to *Horrilakero* having reported that our Signal was damaged by the Fire, we ſent to repair it; and by the precautions abovementioned its Centre was not hard to find.

THE 22d we went to *Poiky-Torneå* upon the banks of the River, where the Signal at the North end of the *Baſe* ſtood, to take the Angles that muſt connect it with the tops of the Mountains. And next Day we ſet out for *Niemiſby*, where the South Signal had been erected, in order to make the like Obſervations. We lay this Night in a pleaſant Meadow; whence Mr. *Camus* parted next Morning for *Pello*, to prepare ſome Hutts where we might lodge, and to order an Obſervatory to be built on *Kittis*, where we were to make our Aſtro-

nomical Obſervations for determining the *Amplitude* of our Arc. *Auguſt.*

AFTER having made our Obſervation at the South end of the *Baſe*, we went up in the Evening to *Cuitaperi*, where our laſt Obſervation for connecting the Baſe with the Triangles was finiſhed the 26th.

HAVING lately received the News of our *Sector* we expected from *England* being arrived at *Torneå*, we made all haſte to return thither, to prepare this Inſtrument, and the others we were to carry to the Obſervatory at *Kittis*; becauſe as the Severity of the Winter was more to be apprehended upon *Kittis* than at *Torneå*, we reſolved to begin our Obſervations for the Amplitude of the Arc, at this end of our Meridian, before the extreme Colds ſhould come on. While every thing was getting ready for the Voyage of *Pello*, we went up to the Spire of a Church ſituated in the Iſle of *Swentzar* (which muſt not be confounded with the Church of the *Finlanders*, in the Iſle of *Biörcköhn*, to the ſouthward of *Swentzar*) and having taken the Angles which this Spire made with our Mountains, we ſailed from *Torneå* the 3d of

Septem. of *September*, with fifteen Boats, the greateſt Fleet that had ever been ſeen upon the River; and lay that Night at *Kuckula.*

NEXT Day we arrived at *Korpikyla*; and while the reſt of the Company continued their rout to *Pello*, I ſet out on foot for *Kakama* with Meſſ^rs *Celſius* and *Outhier*, where we arrived at 9 o'clock at Night in the midſt of a heavy Rain.

THE top of *Kakama* is all of a white Stone diſpoſed in thin Plates, and ſeparated by vertical Planes that cut the Meridian at right Angles; theſe Stones had ſo collected the Rain that had been falling of a long time, that, except the very points of the Rocks, there was not the leaſt Spot that was not full of Water; and beſides, it continued to rain upon us all Night long. It was not poſſible for us to finiſh our Obſervations before the 6th; which coſt us a ſecond Night's lodging upon this Mountain, as wet and cold as the former.

WE left our Station of *Kakama* without regret. And the continual Rains with the encumbered Paſſage we had to make, through

through the Wood, having obliged us to exert our utmoſt diligence, a five hours march brought us back to *Korpikyla*, where we reſted that night, and ſetting out next morning, reached *Pello* on the 9th of *September*, where our whole Company was now once more united. *Septem.*

OUR ſeveral Courſes, in the 63 days we had paſt in theſe Deſarts had furniſhed us as compleat a Set of Triangles as we could have wiſhed for; and an Undertaking begun in ſome ſort at random, without knowing if it was at all practicable, had turned out ſo much better than Expectation, that it looked as if the placing of theſe Mountains had been at our own diſpoſal. The Mountains, with the Church of *Torneå* formed a Figure encloſed on every ſide, within which lay *Horrilakero* as a ſort of Centre, where the ſeveral Triangles that conſtituted it, met. The Figure it ſelf was an oblong Heptagon, placed in the direction of the Meridian, and happened, from a Property of Polygons, to be capable of a Verification that is ſingular in this ſort of Operations. The Sum of the Angles of a Heptagon upon a Plane is 900 Degrees; and as ours was upon a convex Surface, the Sum of its Angles muſt neceſſarily be ſome-

Septem. what greater: accordingly after having obſerved 16 Angles, we found it to amount to $900^{\circ}. 1'. 37''$. Near the middle of the *Heptagon* lay our *Baſe*, the longeſt that was ever uſed, and in the planeſt Surface, ſeeing it was upon the Ice of the River we were to meaſure it. The length of our Baſe warranted the Preciſion of our Meaſures of the Heptagon; and its Situation in the midſt of ſo ſmall a number of Triangles ſecured us againſt any Error of conſequence.

BESIDES, the Arc of the Meridian we were to meaſure was of a juſt length to give our Operations the greateſt degree of Certainty. If there is this advantage in making uſe of large Arcs, that the Errors one may commit in determining the *Amplitudes* are the ſame, whether the Arc is great or ſmall, and that a ſmall Arc will be more affected by the ſame Error than a great one: on the other hand, the Errors in the Trigonometrical Concluſions will be ſo much the more conſiderable as the Length meaſured is greater, and as the number of Triangles increaſes. If their number is very great, and if there is no Opportunity of correcting the Work, by the help of different Baſes, theſe laſt Errors may multiply each other into a Sum that

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shall more than ballance the advantage arising from the largeness of the Arc. I had, before I left *Paris*, read a *Memoire* upon this Subject to the *Academy*, wherein I determine the length of the Arc that gives the greatest degree of Certainty. Its quantity depends upon a Comparison of the Exactness with which the Horizontal Angles can be taken, with that with which the distance of a Star from the *Zenith* can be observed. And if my Reasonings in that Paper are applied to our Operation, it will appear that an Arc either much longer or much shorter would not so well have served our purpose. *Septem.*

IN taking the Angles between our Signals, we made use of a *Quadrant* of two foot *Radius*, with a *Micrometer* fitted to it, which being verified a great many times round the *Horizon*, always gave the Sum of the Angles very nearly equal to 360°. We took care to place its Centre in the Centre of our Signals. Each made his Observation, and wrote it down apart: and then we took the *Mean* of all these Observations, which indeed differed very little from one another.

UPON every Mountain we had taken care to mark the Elevation or Depression of the

Septem. the adjoining Signals ; and upon theſe Obſervations is founded the Reduction of the Angles of our Figure to the Plane of the *Horizon.*

OUR Succeſs in this firſt part of our Work, where we might have met with Difficulties that it was impoſſible for us to get over, gave us freſh Courage for that which remained, where Labour only and Induſtry were required.

IN a Series of Triangles, joined to each other by Sides that are common, and whoſe Angles are known ; if a Side of any one of theſe Triangles is given, it is eaſy to find all the reſt. We could not then fail to know exactly the diſtance between the Spire of the Church of *Torneå*, which terminated our Heptagon on the South, to its North Extremity at the Signal of *Kittis*, once we had meaſured the length of our Baſe.

THIS Operation might well be put off till Winter ; when we ſhould have all the Leiſure and all the Ice we could deſire. So we turned our Thoughts to the other Branch

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of our Work, the Determination of the Arc *Septem.* of the Meridian that lies between *Torneå* and *Kittis.* I have already explained wherein this Determination consisted. We had to observe by how much the same fixt Star, as it passes the Meridian, appears higher or lower at *Torneå* than at *Kittis.* Or in other words, by how much this Star, as it passes the Meridian, is nearer or farther from the Zenith of the one than of the other of these two Places. The difference between these two Heights, or these two Distances from the *Zeniths*, is the *Amplitude* of the Arc of the Meridian between *Kittis* and *Torneå*. The Operation is simple; it is not even necessary to know the absolute distances of the Star from the Zenith of each Place, it is sufficient if we have their Difference. Yet, with all its Simplicity, it requires the most scrupulous Exactness and Caution. For this purpose we had procured a Sector of about 9 foot Radius, like that which Mr. *Bradley* uses, and with which he made his curious Discovery of the *Aberration* of the fixt Stars. It was made at *London* under the Direction of that ingenious Artist Mr. *Graham*, a Fellow of the *Royal Society*, who had exerted himself to give it all the Advantages and all

Septem. the Perfection that could be wifhed for. He had even taken the trouble to divide its Limb with his own hands.

IT were endlefs to give a particular defcription of every thing that is remarkable in this Inftrument. The main Part is very fimple; but its Size, the great number of Pieces there are for rendering it manageable, the Weight of a large Pyramid twelve foot high, that fupports it; all this together made it no eafy matter to raife it to the top of a Mountain of *Lapland*.

WE had built two Obfervatories upon *Kittis*; in the one was a Quadrant of two foot Radius, a Clock of Mr. *Graham*'s, and an Inftrument which we owed to the fame Gentleman, confifting of a Telefcope perpendicular to, and moveable about an horizontal Axis. This we placed precifely at the Center of the Signal that made the angular Point of our laft Triangle. Its Ufe was to determine the direction of our Triangles with refpect to the Meridian. The other Obfervatory, which was much larger, was built fo near the firft, that the Voice of him that counted the Pendulum's Vibrations could

could be distinctly heard from the one to the other. The Sector almost took up the whole Room. What difficulty we had in carrying up so many Instruments to the top of the Mountain, I shall not mention; it is sufficient that we carried them up. The Sector's Limb we placed exactly in the Plane of a Meridian Line which we had traced; and verified its Situation by the time of the Passage of a Star, several Altitudes of which we had taken. In short, every thing was in readiness for beginning our Observations, by the 30th of *September*; and the day following we made several upon the Star δ of the *Dragon*, all agreeing to within less than 3 Seconds. *Septem.*

IN the mean time, other necessary Observations were not neglected; we regulated our Clock every day by correspondent Altitudes of the Sun; and observed with the above mentioned Instrument, the Passage of the Sun in the Meridian, and the Hour when he past the Verticals of *Niemi* and *Pullingi*. By this means we determined the Position of our Heptagon, with regard to the Meridian: and taking the *Mean* of eight such Observations, none of which differed from another by a full Minute, we found the

Septem. Angle which a Line joining the Signals of *Kittis* and *Pullingi* makes with the Meridian of *Kittis* to be 28°. 51′. 52″.

ALL theſe Obſervations were performed very ſucceſsfully: but the Rains and Fogs had ſo retarded them, that we were like to fall into a Seaſon of the Year that muſt cut off our Return to *Torneå*. Yet it was there we had to make the like Obſervations of the ſame Star: And this we wiſhed to have done as ſoon as poſſible, leſt the Motion of the Star ſhould, in a longer interval of Time, produce ſome Error, in caſe it had any Motion to us unknown.

IT is evident that this whole Operation depending upon the difference of the Meridian-Altitudes of the ſame Star ſeen from *Kittis* and from *Torneå*; this Star muſt, during the time of the Obſervations, either keep fixt to the ſame Point of the Heavens, or at leaſt, if it does not, the Laws of its Motion muſt be known, that the difference of Altitude ariſing from its proper Motion may not be confounded with that which proceeds from the Curvature of the Arc of the Terreſtrial Meridian.

ASTRONOMERS have, many ages ſince, obſerved a Motion of the fix'd Stars round the Poles of the *Ecliptic*, producing the *Preceſſion* of the *Equinoxes*, and a Change of *Declination* in the Stars. This can be eaſily taken into the account in the preſent Caſe. *Septem.*

BUT the Stars have another Change of *Declination*, which, however lately taken notice of, we may depend upon as ſurely as on that other. For though Mr. *Bradley* is the original Diſcoverer of this Variation, yet his Accuracy, and the Inſtrument he uſes, render his Obſervations equivalent to thoſe of many Ages. He has found, that in obſerving any Star for a whole Year together, it is ſeen to deſcribe in the Heavens a ſmall *Ellipſis*, whoſe great Axis is about 40″. This *Aberration* of the fixt Stars ſeemed at firſt ſubject to ſo great Varieties, that it was not till after a long Courſe of Obſervation that Mr. *Bradley* diſcovered the Theory upon which this Motion, or rather this Appearance depends. And if no leſs than the Accuracy of that Gentleman could have diſcovered this *Phenomenon*, no leſs than his Penetration

Septem. could have aſſigned its Cauſe. I ſhall not undertake to explain his Syſtem, which may be ſeen to much better purpoſe in *Phil. Tranſ.* N°. 406. I ſhall only add, that this change of Place in the fixt Stars ſeen from the Earth, proceeds from two Motions combined, that of the Rays of Light that come from the Star, and that of the Earth in its Orbit. If the Earth were fix'd, in order to look at a Star through a Teleſcope, the Teleſcope muſt have a certain Inclination, that a Ray of Light from the Star paſſing along its Axis, may reach the Eye. But if the Earth, carrying the Teleſcope along with it, moves with a Velocity that has any ſenſible Proportion to the Velocity of Light, its Inclination muſt now be altered, elſe a Ray of Light coming along its Axis cannot enter the Eye: and the different Poſitions of the Teleſcope will depend on the ſeveral Directions in which the Earth moves at different times of the Year. A Calculation founded upon theſe *Data*, the Velocity (and Direction) of the Earth in its Orbit, and the Velocity of the Rays of Light, which is known from other Experiments, will produce a difference of *Declination* of the fixt Stars, agreeing with Mr. *Bradley*'s Obſervations; and thus

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by increaſing or diminiſhing the Star's Decli- *Septem.*
nation, by the Angles that reſult from this Calculation, we may conſider it as having remained abſolutely fixt during the Interval of our Obſervations.

ALTHOUGH the annual Motion of the fixt Stars agrees perfectly with this Theory, yet Mr. *Bradley* has diſcovered that they have ſtill another Motion, incomparably ſlower than theſe two mentioned, and which is not ſenſible but at the end of ſeveral Years. In the moſt ſcrupulous Strictneſs, this too ſhould be taken into the account. But our Obſervations lay all within ſo narrow a compaſs of time, that its effect muſt have been quite inſenſible, or at leaſt ſmaller than we could hope to meaſure with our Inſtruments. I did indeed conſult Mr. *Bradley*, to learn if he had any late Obſervations of the two Stars we made uſe of to determine the Amplitude of our Arc. Although he had not obſerved them, becauſe they are too far from his *Zenith* for his Inſtrument to take them in, yet he was pleaſed to ſend me his laſt Diſcoveries upon the *Aberration*, and this new-diſcovered Motion of the fixt Stars: and the Correction or Equation he ſent me

Septem. for our *Amplitude*, in which he has had regard to the *Preceſſion* of the *Equinoxes*, the *Aberration*, and this *new Motion*, differs not ſenſibly from that which we made for the *Preceſſion* and *Aberration* only; as will appear from the detail of our Operations.

THOUGH then we may with ſufficient certainty depend upon the Correction for the *Aberration*; yet for the ſake of ſuch as may ſcruple to admit Mr. *Bradley*'s Theory, or may ſuſpect ſome other undiſcovered Motion in the fixt Stars, we wiſh'd that this Correction might be very ſmall; and, for this purpoſe, that the interval between our Obſervations, at *Kittis* and at *Torneå*, might be the ſhorteſt poſſible.

WE had had ſome Ice ever ſince the 19th of *September*, and Snow on the 21ſt. Some part of the River was already froze; and this firſt imperfect Ice might render it impaſſable either to Boats or Sledges for a great while.

BY ſtaying any longer at *Pello* we run a riſque of not being able to return to *Torneå*, till the time between our Obſervations ſhould be

be longer than we wished. We might likewise lose sight of our Star, by the too near approach of the Sun in his annual Course; in which case we must have return'd to *Kittis*, in the midst of Winter to make new Observations upon another Star: And to pass the Winter Nights in making Observations upon the top of a Mountain, was a thing not to be attempted. *Octob.*

IF we set out presently, we were in danger of being stopt by the Ice with all our Instruments, we knew not where, nor for how long time. Thus too our Observations upon *Kittis* might be rendered of no use; a Loss which it must have been very difficult to retrieve in this Country, where all Summer long we could not pretend to observe any Star within the reach of our Instrument, on account of their smallness, and their being hid by continual Day-light: And where the Severity of the Winter rendered Observations upon *Kittis* impracticable.

HAVING carefully weighed all the difficulties on either side, we resolved to venture on the Journey. Mess^{rs} *Camus* and *Celsius*

Octob. *Celsius* ſet out with the Sector the 23d. Meſſ^rs *Clairaut* and *le Monnier* followed next Day. And the Abbé *Outhier* and I on the 26th. And by a ſingular good Fortune landed ſafe at *Torneå* on the 28th of *October*; the People of the Country aſſuring us they had ſcarce ever known the River navigable at that time of the Year.

OUR Obſervatory at *Torneå* being already prepared for receiving the Sector, we fixed it in the Plane of the Meridian. The firſt of *November* it began to freeze harder, and on the morrow the River was quite ſhut up. The Ice, which thawed no more, was preſently covered over with Snow. And this vaſt body of Water, but a few days before full of Swans and other Water-Fowls, was now one immenſe Plain of Ice and Snow.

Novem. ON the 1ſt of *November* we began to obſerve the ſame Star we had obſerved at *Kittis*; and with the ſame precautions and ſucceſs, the greateſt differences of our Obſervations amounting but to one Second. In all which Obſervations, a faint Day-light had ſerved to illuminate the Threads of the Micro-

Micrometer. And taking the Mean of all our Obſervations, the Parts of the *Micrometer* being reduced to Seconds, and due regard had to the Change of Declination cauſed by the Preceſſion of the Equinoxes and other Motions of the Star, our *Amplitude* came out to be 57′. 27″. *Novem.*

OUR Work was now in a manner compleated. It was really determined whether the Earth was *flat* or *prominent* towards the Poles, without our knowing, however, on which ſide of the Queſtion the Determination fell, becauſe we had not yet meaſured our *Baſe*. This was an Operation in itſelf quite ſimple and eaſy, being no more than ſurveying the diſtance between the two Signals we had erected laſt Summer; but then this Survey was to be made upon the Ice of a River in *Lapland*, in a Country where the Cold was growing every day more inſupportable; and the diſtance itſelf more than three Leagues.

WE were adviſed to put off this Survey till the Spring; becauſe the Days ſhould then be longer, and beſides, the firſt meltings of the Snow, which are immediately *Decem.*

Decem. froze again, would turn its Surface into a Cruſt ſtrong enough to bear us; whereas, in the heart of Winter the Snows are commonly in the form of a ſmall dry Duſt, four or five foot deep, which it is impoſſible to paſs over. But the Apprehenſions of being ſurprized by a Thaw, however ill founded they may appear in the midſt of a Froſt that was growing keener every day, overballanced all other Conſiderations. What if we ſhould come too late, ſaid we, in the Month of *May*, and thus be entirely diſappointed in our Deſign.

IN the mean time, as we did not know whether the Snow upon the River might not be already too deep, Meſſ^rs *Clairaut*, *Outhier* and *Celſius*, went on the 10th of *December* to view it. They found its depth conſiderable, yet not ſuch as to make us deſpair of meaſuring our Line; ſo we went all together to *Öfwer-Torneå*.

Mr. *Camus*, aſſiſted by the Abbé *Outhier*, employed the 19th and 20th in adjuſting eight Rods, each 30 foot long, by means of an Iron Toiſe we had brought from *France*, which during this Operation we kept in

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a place where Mr. *de Reaumur*'s Thermometer ſtood at 15 Degrees below 0, and that of Mr. *Prins* at 62; the Degree of Heat at *Paris* in *April* and *May*. Our Rods once adjuſted, were in no danger of ſuffering any Alteration in their length from the Cold. For we had found that Heat and Cold are far from producing any ſuch Extenſion and Contraction in Firr as they are known to do in Iron. All the Experiments we made produced differences in the length almoſt imperceptible. From ſome of them I was even inclined to think, that Wood is by the Cold rather lengthned than contracted; whether it is that a little Sap remaining in thoſe pieces of Wood we made trial with, might poſſibly freeze and ſwell as liquids do when they are expoſed to the Cold, and thus communicate ſomewhat of their Extenſion to the Wood. Mr. *Camus*'s care in adjuſting theſe Rods had been ſuch, that notwithſtanding their great length, when we applied their Extremities between two pieces of Iron, the thickneſs of a leaf of the fineſt Paper more or leſs, would allow them to paſs very freely or not at all. *Decem.*

Decem. ON *Friday* the 21ſt of *December*, the Day of the Winter Solſtice, and a pretty remarkable one for ſuch an Enterprize, we began the meaſure of our *Baſe* towards *Avaſaxa*, where it lay. In this Seaſon the Sun but juſt ſhowed himſelf above the Horizon towards Noon. But the long Twilights, the whiteneſs of the Snow, and the Meteors that are continually blazing in this Sky, furniſhed us light enough to work four or five hours every day. At 11 in the Forenoon we left the *Curate*'s Houſe, where we had taken up our Quarters till this Work ſhould be finiſhed, and went upon the River to begin our Survey; attended by ſo many Sledges, and ſo great an Equipage, that the *Laplanders*, drawn by the novelty of the Sight, came down from the neighbouring Mountains. We parted ourſelves into two Bands, each of which carried four of the Rods juſt now mentioned. I ſhall ſay nothing of the Fatigues and Dangers of this Operation. Judge what it muſt be to walk in Snow two foot deep, with heavy Poles in our hands, which we muſt be continually laying upon the Snow and lifting again: In a Cold ſo extreme, that whenever

we would taſte a little Brandy, the only *Decem.* thing that could be kept liquid, our Tongues and Lips froze to the Cup, and came away bloody: In a Cold that congealed the Fingers of ſome of us, and threatned us with yet more diſmal Accidents. While the Extremities of our Bodies were thus freezing, the reſt, through exceſſive Toil, was bath'd in Sweat. Brandy did not quench our thirſt; we muſt have recourſe to deep Wells dug thro' the Ice, which were ſhut almoſt as ſoon as opened, and from which the Water could ſcarce be conveyed unfrozen to our Lips; and muſt thus run the hazard of the dangerous contraſt which iced Water might produce in our heated Bodies.

OUR Work however advanced apace, ſix days labour had brought it to within about 500 Toiſes, where we had not been able to plant our Stakes ſoon enough. So we intermitted our meaſuring on the 27th, which Meſſ[rs] *Clairaut*, *Camus* and *le Monnier* were to employ in planting theſe Stakes, while the Abbé *Outhier* and I went out upon an extraordinary enough Adventute.

LAST

Decem. LAST Summer we had omitted an Obſervation of very ſmall moment, and which might have been overlooked in a Country where the making Obſervations was leſs troubleſome than here. We had forgot to take the height of an Object that we made uſe of in meaſuring, from the Top of *Avaſaxa*, the Angle between *Cuitaperi* and *Horrilakero*. And to meaſure this height, I undertook to go with a Quadrant to the top of the Mountain; ſo ſcrupulouſly careful were we that nothing ſhould be wanting to the perfection of our Work. Imagine a very high Mountain, full of Rocks, that lie hid in a prodigious quantity of Snow, as well as their Cavities, wherein you may ſink thro' a Cruſt of Snow as into an Abyſs, and the Undertaking will appear ſcarce poſſible. Yet there are two ways of performing it. One is by walking, or rather ſliding along, upon two ſtrait Boards eight foot in length, which the *Finlanders* and *Laplanders* uſe to keep them from ſinking into the Snow. But this way of walking requires long practice. The other is by truſting yourſelf to a *Rain-Deer*, who is uſed to perform ſuch Journeys.

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THE Machine which theſe Animals *Decem.* draw is a ſort of Boat ſcarce large enough to hold the half of one's Body. As this travelling in the Snow is a kind of Navigation, that the Veſſel may ſuffer the leſs reſiſtance in its Courſe, it has a ſharp Head and a narrow Keel, like an ordinary Boat; and on this Keel it tumbles ſo from ſide to ſide, that if one takes not good care to ballance himſelf, it will be in danger of over-ſetting every moment. It is fixt by a thong to the Collar of the Rain-Deer, who, as ſoon as he finds himſelf on a firm beaten Road, runs with incredible Fury. If you would ſtop him, it avails little to pull a ſort of Rein which is tied to his Horns. Wild and unmanageable, it will only make him change his Track, or perhaps turn upon you, and revenge himſelf by kicking. If this happens to a *Laplander*, he turns the Boat over him, and uſes it as a Buckler againſt the Attacks of the Rain-Deer. But as we were Strangers to this Adreſſe, we might have been killed before we could put ourſelves in ſuch a poſture of Defence. Our only Defence was a little Stick each of us had got in his hand, by way of Rudder

Decem. to ſteer our Courſe, and keep clear of the Trunks of Trees. In this manner was I to climb *Avaſaxa*, accompanied by the Abbé *Outhier*, two Men and a Woman of the Country, and Mr. *Brunnius* their Curate.

THE firſt part of our Journey was done in a moment; our flight over the plain beaten Road from the Curate's Houſe to the foot of the Mountain can be compared only to that of Birds. And tho' the Mountain, where there was no track, very much abated the ſpeed of our Rain-deer, they got at length to the top of it; where we immediately made the Obſervation for which we came. In the mean time our Rain-deer had dug deep holes in the Snow, where they browzed the Moſs that covers the Rocks. And the *Laplanders* had lighted a great Fire, at which we preſently joined them to warm ourſelves. The Cold was ſo exceeding great, that the Heat of this Fire could reach but to a very ſmall diſtance. As the Snow juſt by it melted, it was immediately froze again, forming a hearth of Ice all round.

IF our Journey up hill had been painful, our Concern now was leſt our return ſhould

ſhould be too rapid. We had to come down *Decem.* a ſteep, in Conveyances, which, though partly ſunk in the Snow, ſlid on notwithſtanding, drawn by Animals whoſe Fury in the Plain we had already try'd, and who, though ſinking in the Snow to their Bellies, would endeavour to free themſelves by the Swiftneſs of their flight. We very ſoon found ourſelves at the bottom of the Hill; a moment after, all this great River was croſſed, and we back at the Curate's Houſe.

NEXT day we finiſhed our Survey; and had now no reaſon to regret the Toils we had gone thro', when we ſaw what ſurprizing exactneſs the meaſuring upon a Surface of Ice had given us. The difference between the Meaſures of our two Companies was but four Inches upon a diſtance of 7406 Toiſes 5 feet. An exactneſs not to be expected, and almoſt incredible. We look upon it as an effect of Chance, and that there muſt have been greater differences, but which in the courſe of our Work had compenſated each other; for this ſmall difference of four Inches roſe all in our laſt day's meaſuring. Each of our Bands had meaſured every day the ſame number of

Decem. Toiſes; and the difference every day was but one Inch which the one or the other had gained. This coincidence, which was owing partly to the Ice, and partly to our own Accuracy, ſhewed at the ſame time the perfect equality of our *Rods*; for the ſmalleſt difference in their lengths, muſt, in ſo great a diſtance, have been multiplied to a conſiderable Sum.

WE already knew the *Amplitude* of our Arc; and our Figure, every other way determined, wanted only to be applied to its *Scale*, that is, to the length of our Baſe. This we were now Maſters of; and immediately found that the length of the Arc of the Meridian intercepted between the two Parallels that paſs through the Obſervatories of *Torneå* and *Kittis* is 55023 $\frac{1}{2}$ Toiſes. That the *Amplitude* of this Arc being 57′. 27″. the Degree of the Meridian at the Polar Circle is greater by 1000 Toiſes than it ſhould be according to Mr. *Caſſini*, in his Treatiſe *On the Magnitude and Figure of the Earth.*

THIS Operation ended, we made haſte to get back to *Torneå*, to ſecure ourſelves

selves the best we could against the growing Severity of the Season. *Decem*

THE Town of *Torneå*, at our Arrival on the 30th of *December*, had really a most frightful Aspect. Its little Houses were buried to the tops in Snow, which, if there had been any day-light, must have effectually shut it out. But the Snows, continually falling, or ready to fall, for most part hid the Sun the few moments that he might have showed himself at Mid-day. In the Month of *January* the Cold was increased to that extremity, that Mr. *Reaumur*'s Mercurial Thermometers, which at *Paris*, in the great Frost of 1709, it was thought strange to see fall to 14 Degrees below the freezing point, were now got down to 37. The Spirit of Wine in the others was frozen. If we opened the door of a warm room, the external Air instantly converted all the Vapour in it into Snow; whirling it round in white Vortexes. If we went abroad, we felt as if the Air were tearing our Breasts in pieces. And the cracking of the Wood whereof the Houses are built, as the violence of the Cold split it, continually alarmed us with an approaching in-

Decem. crease of Cold. The Solitude of the Streets was no less than if the Inhabitants had been all dead: And in this Country you may often see People that have been maimed, and had an Arm or a Leg froze off. The Cold, which is always very great, increases sometimes by such violent and sudden Fits, as are almost infallibly fatal to those that happen to be exposed to it. Sometimes there rise sudden Tempests of Snow, that are still more dangerous. The Winds seem to blow from all Quarters at once, and drive about the Snow with such Fury, that in a moment all the Roads are lost. Unhappy he who is surprized by such a Storm in the Fields. His Acquaintance with the Country, or the Marks he may have taken by the Trees, cannot avail him. He is blinded by the Snow, and lost if he stirs but a step.

IF the Earth in this Climate is thus horrible, the Heavens present to the Eye a most beautiful Prospect. As soon as the Nights begin to be dark, Fires of a thousand Colours and Figures light up the Sky, as if designed to compensate, to a Country accustomed to such length of day, the absence of the Sun in this Season. These Fires have not here,

as in the more ſoutherly Climates, any conſtant Situation. Though you may often ſee a luminous Arch fixed towards the North, they ſeem more frequently to poſſeſs the whole Extent of the Hemiſphere. Sometimes they begin in the form of a great Scarf of bright Light, with its Extremities upon the Horizon, which, with a Motion reſembling that of a Fiſhing-Net, glides ſwiftly up the Sky; preſerving in this Motion a direction nearly perpendicular to the Meridian. Moſt commonly, after theſe Preludes, all the Lights unite at the Zenith, and form the top of a ſort of Crown. Arcs like thoſe we ſee towards the North in *France*, are here frequently ſituated towards the South: And oftimes towards both North and South at once. Their Summits approach each other, while the diſtance of their Extremities widens towards the Horizon. I have ſeen ſome of the oppoſite Arcs whoſe Summits almoſt joined at the Zenith: And both the one and the other have frequently ſeveral concentric Arcs beyond it. Their tops are all placed in the Direction of the Meridian, though with a little Declination to the Weſt; which I did not find to be conſtant, and which ſometimes is inſenſible. *Decem.*

Jan^ry, 1737. ſenſible. Some of theſe Arcs have their greateſt width at the Horizon; which contracting as they riſe, gives them the form of more than half a great Ellipſe. It were endleſs to mention all the different Figures theſe Meteors put on, and the different Motions wherewith they are agitated. Their Motion is moſt commonly like that of a pair of Colours waved in the Air, and the different Tints of their Light give them the appearance of ſo many vaſt Streamers of that ſort of Taffetas which we call *changeable*. Sometimes they line a part of the Sky with Scarlet. On the 18th of *December* I ſaw at *Ofwer-Torneå* a Phenomenon of this kind, which raiſed my Admiration, in the midſt of all the Wonders I was now every day accuſtomed to. There appeared to the South, a great ſpace of the Sky tinged with ſo lively a red, that the whole Conſtellation of *Orion* look'd as if it had been dipt in blood. This Light, which was fixt at firſt, ſoon moved, and changing into other colours, Violet and Blue, ſettled into a Dome, whoſe top ſtood a little to the South-weſt of the Zenith. The Moon ſhone bright, but did not in the leaſt efface it. In this Country, where there are Lights of ſo many diffe-

different colours, I never ſaw but two that were red; and ſuch are taken for Preſages of ſome great Misfortune. After all, when People look at theſe Phenomena with an unphiloſophic eye, it is not ſurprizing if they diſcover in them fiery Chariots, Armies engaged, and a thouſand other Prodigies. *Jan^ry.*

WE had ſhut our ſelves up at *Torneå* in a kind of inaction, till the Month of *March* that we could venture out upon new Diſcoveries,

IN the mean time, the great difference of our Arc, from what it muſt have come out upon Mr. *Caſſini*'s Hypotheſis, aſtoniſhed us; and we reſolved, however inconteſtable our Operations were, to ſubmit the whole Proceſs to a moſt rigorous Examination.

AS for our Triangles, their Angles had been obſerved ſo often, and by ſo great a number of Perſons, that this part of our Work could fall under no manner of ſuſpicion. It had even an advantage above any thing that has been done in this kind. It has commonly been thought ſufficient to find two Angles of a Triangle by Obſervation, and the third by ſubtracting their

Sum

Jan'ry. Sum from 180 Degrees. This Method would have been extremely convenient for us, and would have ſaved us many a diſagreeable hour upon the tops of theſe Mountains; yet we had willingly ſacrificed this Convenience to the pleaſure of knowing from actual Obſervation every Angle in our Figure.

BESIDES, tho' to determine the Diſtance between *Torneå* and *Kittis*, no more than 8 Triangles were abſolutely neceſſary, we had obſerved ſeveral ſupernumerary ones, and by this means our Heptagon furniſhed us Combinations or Series of Triangles without number.

THUS one part of our Work had been done, one may ſay, a great many times over; and there remained only to calculate and find what different Lengths might reſult from theſe different Series of Triangles. We had the patience to make trial with no leſs than 12 Series; and though ſeveral of our Angles were too ſmall to be admitted in ſuch Calculations, the higheſt difference in the diſtances of *Kittis* and *Torneå*, deduced from theſe Series, roſe but to 54 Toiſes. We pitched upon two, which we judged preferable

ferable to the others, and which gave a difference of $4\frac{1}{2}$ Toiſes. And the *Mean* of this we uſed to determine the Length of our Arc. *Jan.*

SUCH a perfect Agreement would have ſurprized us, if we had not remembred what pains and time had been beſtowed upon the taking of theſe Angles. Eight or nine Triangles had coſt us 63 days; and every Angle had been obſerved ſo often, and by ſo many different Perſons, that the *Mean* of them all could not but come very near the Truth.

THE ſmall number of our Triangles enabled us to make an odd enough Calculation, which gives the ſtrict limits of all the Errors that bad ſkill and bad luck put together can produce. We made a ſuppoſition, that in every Triangle we had committed an Error in two of the Angles of 20″ each, and in the third of 40″; and that all theſe Errors lay the ſame way, tending always to diminiſh our Arc. And having made a computation upon this ſtrange Suppoſition, we found that the Error could amount to but $54\frac{1}{2}$ Toiſes.

Jan^ry.

OUR extreme Care in meaſuring the Baſe left no room to ſuſpect we had failed in this part. The agreement of ſo many ſkilful Perſons, who writ down, each ſeparately, the number of Rods, and the repeating of this Meaſure with a difference of no more than 4 Inches, were a more than ſufficient ſecurity.

WE turned therefore the reſt of our Scrutiny upon the *Amplitude* of the Arc. The ſmall difference there was amongſt our Obſervations, both at *Kittis* and at *Torneå*, left no doubt as to the manner of Obſerving.

AND conſidering the Solidity and Conſtruction of our Sector, with the Precautions we had taken in carrying it from Place to Place, there was no great ground to fear it had met with any accident to put it out of order.

ITS Limb, Teleſcope and Centre, make up but one Piece, and the Threads in the Focus of the Object-Glaſs, are two Silver Wires, fixed by Mr. *Graham* himſelf, ſo as they can ſuffer no change in their ſituation, and remain

always in the ſame degree of Tenſion, whether it is hot or cold. Thus the only diſorder that could happen to this Inſtrument would be the bending of its Teleſcope. *Janry.*

BUT upon calculating the effects of any Alteration of this ſort, it will appear, that to occaſion an Error of one Second in the Amplitude of our Arc, there muſt be a bending ſo conſiderable as to be very eaſily perceived. Incloſed in a ſtrong Caſe it had been conveyed in a Boat from *Kittis* to *Torneå*, under the care of one of us, put on ſhore at the Cataracts, and carried by Men.

THE ſituation of the Star which we had obſerved, enſured us againſt what happens to the Teleſcopes of large Inſtruments, when they are directed to an Object at a conſiderable diſtance from the Zenith; their weight alone muſt bend them while they are in this inclined Poſition: and the method of obſerving with the two different Sides of the Inſtrument, tho' it may prevent ſome other Miſtakes, cannot correct this. For if in obſerving with the face of the Inſtrument towards the Eaſt, the Teleſcope has ſuffered any Inflexion, when you turn its face to the Weſt,

Jan^ry. West, it will suffer nearly the same Inflection the contrary way; so that the same Point may answer to the Zenith in either Observation, and yet the Star's distance from the Zenith not be justly measured. The distance of our Star from the Zenith of *Kittis* was but half a Degree, and consequently our Telescope, in a situation so erect, could suffer no alteration.

THOUGH, on all these accounts, we had no reason to doubt of our Amplitude's being accurately measured; yet we would be assured by experience that it was so; and for this purpose employed a Method which was indeed the most troublesome, but must be at the same time the most satisfactory, as it would at once discover to us the goodness of our Instrument, and how far we might depend upon the Accuracy of our Observations.

THIS Verification consisted in determining the same Amplitude by the means of another Star. We watched therefore an occasion of making some Observations near one another, which is difficult in a Country where there are seldom three or four clear Nights together. And

And on the 17th of *March* 1737, having begun, at *Torneå*, in the same place as before, to observe α of the *Dragon*, and got three good Observations of this Star; we set out for *Kittis* to make the like Observations there. Our Sector was conveyed upon a Sledge that went very slowly upon the Snow; the softest Carriage that can be imagined. Our new Star was nearer still to the Zenith than the former, being situated but a quarter of a Degree from the Zenith of *Torneå*. *March.*

WE could readily place our Instrument by means of the Meridian Line that had been drawn in our Observatory at *Kittis*; and the 4th of *April*, began our Observations of α; three of which compared with those of *Torneå*, gave for the Amplitude $57'. 30''\frac{1}{2}$, which exceeds that found by the Star δ by $3''\frac{1}{2}$; allowance being made for the Aberration of Light: and if the Aberration is not taken into the account, the difference would not be $1''$. *April.*

A difference so very inconsiderable, that it might be owing to the Errors in observing, and which, as will appear from the Sequel, was still less than it appeared, was a strong Proof both

April. both of the goodneſs of the Inſtrument, and of the truth of our Obſervations.

TAKING now a *Mean* between the Amplitude found by the Star δ and that found by α, the true Amplitude comes to be $57'. 28''\frac{3}{4}$, which compared with the meaſured Length of $55023\frac{1}{2}$ Toiſes, gives for the Degree that cuts the Polar Circle, 57437 Toiſes, exceeding that of Mr. *Picard* between *Paris* and *Amiens* by 377 Toiſes.

BUT it muſt be obſerved, that the *Aberration* of the fixt Stars was not known, nor could be taken into the account by Mr. *Picard.* If his *Amplitude* is corrected by *it*, and by the *Preceſſion* of the *Equinoxes* and *Refraction*, both which he had neglected, it will be $1^{o}. 23'. 6''\frac{1}{2}$, which compared with the diſtance meaſured 78850, gives to a Degree 56925, ſhort of ours by 512 Toiſes.

AND if the *Aberration* was ſet aſide, our Amplitude would be reduced to $57'. 25''$, which compared with the Arc would give to the Degree 57497, exceeding 57060 Toiſes, which Mr. *Picard* had found in a Degree,

Degree, without reckoning the *Aberration* *April.* by 437.

LAST of all; with the Aberration, our Degree differs by 950 Toises from what it should be by Mr. *Cassini*'s Book; and setting aside the Aberration, by 1000.

WHENCE it is evident, *That the Earth is considerably flatted towards the Poles.*

DURING our whole Stay in the *frigid Zone*, the Cold was so excessive, that the 7th of *April* at 5 in the Morning, the Thermometer was fallen to 20 Divisions below the Point of Freezing, although every Afternoon it rose two or three Divisions above it: a difference of height not much less than that which the greatest Heats and Colds that are felt at *Paris* usually produce in the Thermometer. Here, in the space of 12 hours, we had all the variety that is felt in the temperate Zones in a whole Year.

WE carried our Scrutiny even to the direction of the Heptagon, with respect to the Meridian. This Direction, as above mentioned, had been determined upon *Kittis* by

April. a great number of Obſervations of the Sun's Paſſage by the Verticals of *Niemi* and *Pullingi*, and it was not probable we had miſplaced our Figure, the Triangles that compoſed it being ſo few in number, and the Sum of its Angles coming ſo near to juſt 900 Degrees: yet we choſe to ſettle this Point once more, at *Torneå*.

WE took a different Method from that which we had uſed at *Kittis*. We meaſured the Angle between the Sun in the Horizon, and one of our Signals, marking the time of the Obſervation: and three ſuch Obſervations gave us, at a *mean*, the ſame Angle, within 34″, as we had found at *Kittis*.

HAVING thus gone over every part of our Work a ſecond time, it remained only to examine the original Conſtruction and Diviſion of our Sector. There was not the leaſt reaſon to ſuſpect it; but having ſome leiſure till the Seaſon for travelling ſhould come on, we would employ a part of it in this Examination. Our Method deſerves a particular Deſcription, being ſingular; and of uſe to ſhew what may be expected from ſuch

ſuch an Inſtrument, and how to diſcover any Alteration it may chance to receive. *May.*

THE 4th of *May*, we laid out (ſtill upon the Ice of the River) a Radius of 380 Toiſes, 1 Foot, 3 Inches, 0 Line; having meaſured it twice without finding any difference. We planted two firm Poſts with two *Marks* in a Line perpendicular to the Extremity of this Radius, and having meaſured the diſtance between the Centers of the two *Marks*, we found it to be 36 Toiſes, 3 F. 6 In. $6\frac{2}{3}$ Lin. This Line was our Tangent.

WE placed the Sector horizontally in a Room, upon two firm Supports that reſted upon a Vault, ſo that its Center was preciſely at the Extremity of our Radius of 380 Toiſes, 1 F. 3 Inches; and five of us having ſeverally taken the Angle between the two Marks, the greateſt difference amongſt our Obſervations not amounting to full 2″, their *Mean* was $5^{\circ}. 29'. 52'';7$. Now Mr. *Graham* had ſignified to us that the Arch of $5\frac{1}{2}$ Degrees on the Limb of this Inſtrument was too ſhort by $3''\frac{3}{4}$; ſubtracting theſe $3''\frac{3}{4}$ our Angle is $5^{\circ}. 29'. 48''. 95$. But the Angle,

 by

May. by Calculation, is $5^{\circ}.\ 29'.\ 50''$, differing from that obſerved by no more than $1''\frac{1}{20}$.

IT may ſeem ſurprizing that a Sector which, in ſo temperate a Climate as that of *London*, was found to be of $5^{\circ}.\ 29'.\ 56''\frac{1}{4}$, and was divided in a Room probably not cold, ſhould at *Torneå* remain preciſely of the ſame length, at the making this trial, when its parts were no doubt contracted by the Cold. But the ſurprize will ceaſe, if it is remembered, that this Inſtrument is all of the ſame matter, and that conſequently all its parts muſt be contracted proportionally, its figure remaining ſimilar to what it was before, as we found it had done.

HAVING found the total Arc of the Sector ſo exquiſitely juſt, we would next ſee if the two Degrees of its Limb, which we had uſed, the one for δ and the other for α, were perfectly equal. Mr. *Camus*'s Adreſſe, to which we had been obliged upon ſo many other occaſions, helped us to make this Compariſon with all the accuracy imaginable. And taking the Mean of 5 ſeveral Obſervations made by different Perſons, the Degree we had made uſe of for δ came out greater by $1''$ than that which we had uſed for α.

WE

May.

WE were surprized to see that this inequality of the two Degrees made the small difference between our two Amplitudes still less, reducing it from $3''\frac{1}{2}$ to $2''\frac{1}{2}$. And it will appear from the detail of our Operations, and from the Method we used to discover it, that this difference, small as it is, may be reckoned upon with great Certainty.

IN the same manner we verified not only the total Arc of the Sector, but different Arcs which we compared together. And this Verification from Arc to Arc, joined to that of the whole, satisfied us that we could neither have wished nor hoped for any thing more exquisite in its kind.

WE could not conceive any thing more that remained for us to do, with respect to the measure of a Degree of the Meridian. For I shall say nothing at present of our Experiments upon *Gravitation*; a Subject no less important than the other, and which we treated with equal care. Let it suffice to assure whoever has a mind to examine the Earth's Figure by the Weight of Bodies, after the Example of Sir *Isaac Newton*, Mr. *Huy-*

May. *gens*, and others (to whoſe Names may I be permitted to add my own) that they will find all the Experiments we made in the North to that purpoſe, as well as thoſe we are told Meſſ[rs] *Godin*, *Bouger*, and *la Condamine* have made at the Equator, will concur in making the Earth flat towards the Poles.

MEAN time, the Sun was now come nearer, or rather no more quitted us. It was curious enough to ſee him enlighten for ſo long a time, a whole Horizon of Ice, and to ſee Summer in the Heavens, while Winter ſtill kept poſſeſſion of the Earth. We were now in the Morning of that long Day of ſeveral Months; yet the Sun, with all his aſſiduity, had wrought no change either upon the Ice or Snows.

THE 6th of *May* it began to rain, and ſome Water appeared on the Ice of the River. At Noon a little Snow melted; but in the Evening, Winter reſumed his Rights. At length, on the 10th of *May*, the Earth which had been ſo long hid, began to appear; ſome high Points that were expoſed to the Sun, ſhewed themſelves, as the tops of the

 Moun-

Mountains did after the Deluge, and all the Fowls of the Country returned. Towards the beginning of *June*, Winter yielded up both Earth and Sea. We bethought us forthwith of our Journey back to *Stockholm*; and ſet out the 9th of *June*, ſome of us by Land, and others by Sea. But the Sequel of our Adventures, and our Shipwreck in the Gulph of *Bothnia*, belong not to the preſent Subject. *June.*

OBSERVATIONS
Made at the Polar Circle.

BOOK I.

PART I.
Containing the Operations for measuring the Degree of the Meridian.

CHAP. I.
Obſervations for forming the Triangles, and determining their Poſition, with reſpect to the Meridian Line.

I.
The Angles Obſerved.

ALL theſe Angles were taken with a Quadrant of 2 foot Radius, arm'd with a Micrometer; which Inſtrument verified ſeveral times round the Horizon, gave always the Sum of the Angles very near equal to 360°.

THE

THE Decimals of Seconds are marked as they aroſe in the arithmetical Reduction of the parts of the Micrometer to Seconds; but we would not for that be thought to pretend to an imaginary Exactneſs.

FOLLOWS a Table of the Angles obſerved, with the Elevations of the Objects, where the Sign + or — marks their being *above* or *below* the Horizontal Line.

Angles obſerved.	*Angles reduced to the Horizon.*	*Elevations.*	
In the Spire of the Church of Torneå.			
° ′ ″	° ′ ″	′ ″	
CTK.. 24 23 0,2	24 22 58,8	*C*.....0 0	Fig. 1.
And by the Reduction on account of the Centre of the Inſtrument its being 5 foot diſtant from the Centre of the Spire in the Direction of *Cuitaperi*			
CTK.........	24 22 54,5		
KTn.. 19 38 20,9	19 38 20,1	*n*.. +3 0	
And by Reduction for the place of the Centre of the Inſtrument.			
KTn.........	19 38 17,8	*K*.. +8 40 The Horizon of the Sea —11 0	

Angles

Upon *Niwa*.

	Angles observed.	Angles reduced to the Horizon.	Elevations.
	° ′ ″	° ′ ″	′ ″
Fig. 1.	*TnK*.. 87 44 24,8	87 44 19,4	*T*... −17 40
	HnK.. 73 58 6,5	73 58 5,7	*K*... +16 50
	AnK.. 95 29 52,8	95 29 54,4	*A*... + 4 40
	AnH=*AnK*−*HnK*	21 31 48,7	*H*... − 0 30
	AnH=21 32 16,9	21 32 16,3	
	Whence *AnH* is	21 32 2,5	
	CnH.. 31 57 5,2	31 57 3,6	*C*... + 10 0

Upon *Kakama*.

Angles observed.	Angles reduced to the Horizon.	Elevations.
TKn... 72 37 20,8	72 37 27,8	*n*..... −22 50
CKn... 45 50 46,2	45 50 44,2	*C*.... − 4 45
HKn.. 89 36 0,4	89 36 2,4	*H*.... − 5 10
HKC=*nKH*−*CKn*	43 45 18,2	
HKC.. 43 45 46,8	43 45 47,0	
HKC.. 43 45 41,5	43 45 41,7	
Whence *HKC* is	43 45 35,6	
CKT=*CKn*+*nKT*	118 28 12,0	*T*.... −24 10
HKN.. 9 41 48,1	9 41 47,7	*N*.... − 8 10

Upon *Cuitaperi*.

Angles observed.	Angles reduced to the Horizon.	Elevations.
		K.... − 6 10
KCn... 28 14 56,9	28 14 54,7	*n*..... −19 0
TCK... 37 9 15,0	37 9 12,0	*T*.... −24 10
HCK 100 9 56,4	100 9 56,8	*H*... − 2 40
ACH.. 30 56 54,4	30 56 53,4	*A*... + 5 0

Angles

Upon *Avasaxa.*

	Angles observed. ° ′ ″	*Angles reduced to the Horizon.* ° ′ ″	*Elevations.* ′ ″
HAP..	53 45 58,1	53 45 56,7	*P*.... + 4 50
HAx...	24 19 34,8	24 19 35,0	*H*.... — 8 0
xAn...	77 47 46,7	77 47 49,5	*x*..... —10 40
xAC...	88 2 11,0	88 2 13,6	*C*.... —14 15
HAn=HAx+xAn		102 7 24,5	*n*..... —20 20
HAC=CAx+xAH		112 21 48,6	
CAn...	10 13 54, 2	10 13 52,8	

Upon *Pullingi.*

	Angles observed.	*Angles reduced to the Horizon.*	*Elevations.*
			H.... —22 0
APH..	31 19 53,7	31 19 55,5	*A*.... —18 10
QPN	87 52 9,7	87 52 24,3	*Q*... —32 40
NPH	37 21 58,9	37 22 2,1	*N*.... —26 50

Upon *Kittis.*

	Angles observed.	*Angles reduced to the Horizon.*	*Elevations.*
NQP..	40 14 57,3	40 14 52,7	*P*.... +22 30
			N... + 1 0

Upon *Niemi.*

	Angles observed.	*Angles reduced to the Horizon.*	*Elevations.*
			P.... +18 30
PNQ	51 53 13,7	51 53 4,3	*Q*... —14 0
PNH	93 25 8,1	93 25 7,5	*H*... — 2 40
HNK	27 11 55,3	27 11 53,3	*K*.... —14 0

Angles

Angles observed.	*Angles reduced to the Horizon.*	*Elevations.*

Upon *Horrilakero.*

	Angles observed.	*Angles reduced to the Horizon.*		*Elevations.*
	° ′ ″	° ′ ″		′ ″
CHn...	19 38 21,8	19 38 21,0	*n*....	—18 15
CHA..	36 42 4,3	36 42 3,1	*A*...	0 0
AHP..	94 53 49,7	94 53 49,7	*P*...	+11 50
PHN	49 13 11,9	49 13 9,3	*N*...	— 5 0
KHn..	16 26 6,7	16 26 6,3	*K*...	—12 30
CHK..	36 4 54,1	36 4 54,7	*C*...	—10 40

Angles for connecting the Base Bb *with the Tops of* Avaſaxa *and* Cuitaperi.

Angles observed.	*Angles reduced to the ſame Plan.*	*Elevations of the Objects ſeen from the Point* B.
	Reducing *ABy*, *y BC*, and *ABz*, *z BC* to the ſame Plan *ABC*, and taking a *Mean* between the two Values of *ABC* thus found, we had	
° ′ ″		° ′ ″
ABb.... 9 21 58,0		
AbB.. 77 31 48,1		
BAb.. 93 6 7,2		*A*..+0 40 30
ABy.. 61 30 5,4		*y*...+1 23 30
yBC.. 41 12 3,4		*C*..+1 4 5
ABz.. 46 7 57,5	*ABC*.. 102° 42′ 13″,5	*z*...+1 11 0
zBC.. 56 34 22,2		
ACB.. 54 40 28,8		
BAC.. 22 37 20,6		

The Letters *x*, *y*, *z*, mark the intermediate Objects that were uſed to take the Angle *ABC* at twice, being greater than 90°.

II.

II.

Obſervations upon Kittis *for drawing the Meridian Line.*

THE Inſtrument with which theſe Obſervations were made conſiſted of a Teleſcope 15 Inches long, moveable round a horizontal Axis to which it was perpendicular. This Inſtrument was placed upon the Centre of the Signal of *Kittis*, where the height of the Pole is 66°. 48′. 20″. and whoſe Longitude Eaſt from *Paris* anſwers, we ſuppoſe in that Calculation, to 1^h. 23′.

THERE was in the ſame place a Clock which we regulated every day by correſpondent Altitudes of the Sun. And the Hour of the paſſage of the Sun's Centre, which we determined by the paſſages of his two Limbs, is in this Table given in *true time.*

Paſ-

Passages of the Sun's Centre by the Vertical of the Signal of Pullingi.

1736. Afternoon.	h	′	″		°	′	″
30 Septemb. at	1	49	49	☉'s Decl. . . .	3	0	40
1 October at	1	50	$7\frac{1}{4}$	☉'s Decl. . . .	3	24	1
2 October at	1	50	26	☉'s Decl. . . .	3	47	19
7 October at	1	51	$54\frac{3}{4}$	☉'s Decl. . . .	5	42	56
8 October at	1	52	$14\frac{1}{2}$	☉'s Decl. . . .	6	6	10

Passages of the Sun's Centre by the Vertical of the Signal of Niemi.

1736. Before noon.	h	′	″		°	′	″
4 October at	11	16	37	☉'s Decl. . . .	4	31	22
7 October at	11	16	$15\frac{3}{4}$	☉'s Decl. . . .	5	40	26
8 October at	11	16	12	☉'s Decl. . . .	6	3	39

CHAP.

CHAP. II.

The Angles formed by the Meridian Line with the Lines drawn from Kittis *to* Pullingi, *and to* Niemi.

THE Method we used, to find from these Observations, the above-mentioned Angles, consists in resolving the two spherical Triangles PZS, PZs, where we have given; the Side $PZ = 23°. 11'. 40''$. being the distance of the Zenith of *Kittis* from the Pole; PS or Ps, the Compliment of the Sun's Declination at the time of Observation; and the Angle ZPS or ZPs, which is known from the time of the Sun's passage by the Vertical Zp or ZN of *Pullingi* or *Niemi*: Whence are found the Angles HZp and HZN, or HQp and HQN, which Lines drawn from *Kittis* to *Pullingi* and *Niemi* make with the Meridian. Fig. 3.

THE

THE Angles deduced from the ſeveral Obſervations are as follows:

The Decl. of *Pullingi*, Weſt.	°	′	″	Decl. of *Niemi*, Eaſt.	°	′	″
30 Sept.	28	51	54				
1 Octob.	28	51	56				
2 Octob.	28	52	5				
4 Octob.	. . . . .			. . . . .	11	23	30
7 Octob.	28	51	43		11	23	23
8 Octob.	28	52	6		11	22	31

Fig. 3. AND having already (*page* 107.) the Angle $NQP = 40°. 14', 52'',7$, theſe Declinations of *Niemi* are changed by ſubtraction into the following of *Pullingi*.

°	′	″
28	51	23
28	51	30
28	52	22

AND all theſe Declinations give, at a Mean, the Declination of *Pullingi*, or the

Fig. 2. Angle $PQM = 28°. 51'. 52''$.

CHAP.

CHAP. III.

The Length of the Base; and the Calculation of the Triangles of the two principal Series.

I.

The Length of the Base.

Bb is the Base. It was measured two several times by two different Companies, whereof each had four Perches of 30 foot in Length. Fig. 1.

	Tois.	*f.*	*inch.*
The first Mensuration gave	7406	5	0
The second	7406	5	4
Between which the mean length is . .	7406	5	2

II.

Calculation of the two Triangles with which all the Series begin.

A B b.

	Angles observed.	Angles corrected for Calculat.
	° ′ ″	° ′ ″
Fig. 1. *A B b*...	9 21 58,0	.... 9 22 0
A b B...	77 31 48,1	.... 77 31 50
B A b...	93 6 7,2	.... 93 6 10
	179 59 53,3	180 0 0

A B C.

ABC...	102 42 13,5	.... 102 42 12
BAC...	22 37 20,6	.... 22 37 20
ACB...	54 40 28,8	.... 54 40 28
	180 0 2,9	180 0 0

BY resolving these two Triangles, the *Base B b* being 7406 Toises, 5 Foot, 2 Inches, the distance *A C*, between *Avasaxa* and *Cuitaperi* is found to be 8659,94 Toises.

AND these two Triangles having been very accurately determined, and their disposition advantageous for finding this distance, *A C* may be henceforth used as a Base.

III. *Cal-*

III.

Calculation of the Triangles of the first Series.

A C H.

Angles observed, reduced to the Horizon.	°	′	″	*Angles corrected for Calculation.*	°	′	″
CAH...	112	21	32,9	....	112	21	17
ACH...	30	56	53,4	....	30	56	47
AHC...	36	42	3,1	....	36	41	56
	180	0	29,4		180	0	0

Fig. 2.

C H K.

CHK...	36	4	54,7	....	36	4	46
CKH...	43	45	35,6	....	43	45	26
KCH...	100	9	56,8	....	100	9	48
	180	0	27,1		180	0	0

C K T.

KCT...	37	9	12,0	....	37	9	7
CKT...	118	28	12,0	....	118	28	3
CTK...	24	22	54,3	....	24	22	50
	180	0	18,3		180	0	0

 AHP

A H P.

	° ′ ″		° ′ ″
AHP...	94 53 49,7	....	94 53 56
HAP...	53 45 56,7	....	53 46 3
APH...	31 19 55,5	....	31 20 1
	179 59 41,9		180 0 0

H N P.

HNP...	93 25 7,5	....	93 25 1
NHP...	49 13 9,3	....	49 13 3
HPN...	37 22 2,1	....	37 21 56
	180 0 18,9		180 0 0

N P Q.

NPQ...	87 52 24,3	....	87 52 17
NQP...	40 14 52,7	....	40 14 46
PNQ...	51 53 4,3	....	51 52 57
	180 0 21,3		180 0 0

TAKING *A C* = 8659,94 Toifes, as found above (*page* 114.) by means of the two Triangles *ABb*, *A B C*; by refolving the foregoing Triangles we find,

	Toifes.
A P =	14277,43
P Q =	10676,9
C T =	24302,64

THESE

THESE Lines form with the Meridian the following Angles,

	°	′	″
PQD =	61	8	8
APE =	84	33	54
ACF =	81	33	26
CTG =	69	49	8

AND the Resolution of the right-angled Triangles *DQP*, *APE*, *ACF*, *CTG*, gives for the parts of the Meridian Line,

	Toises.
PD =	9350,45
AE =	14213,24
AF =	8566,08
CG =	22810,62
QM =	54940,39

for the Arc of the Meridian which passes thro' *Kittis*, and which is terminated by the Perpendicular drawn from *Torneå*.

IV.

Calculation of the Triangles of the ſecond Series.

A C H.

	Angles obſerved, reduced to the Horizon. ° ′ ″		*Angles corrected for Calculation.* ° ′ ″
Fig. 2. *ACH*...	30 56 53,4	....	30 56 47
CAH...	112 21 32,9	....	112 21 17
AHC...	36 42 3,1	....	36 41 56
	180 0 29,4		180 0 0

C H K.

CHK...	36 4 54,7	....	36 4 46
CKH...	43 45 35,6	....	43 45 26
KCH...	100 9 56,8	....	100 9 48
	180 0 27,1		180 0 0

C K T.

CKT...	118 28 12,0	....	118 28 3
CTK...	24 22 54,3	....	24 22 50
KCT..	37 9 12,0	....	37 9 7
	180 0 18,3		180 0 0

H K N.

H K N.

HKN...	9	41	47,7	....	9	41	50
HNK...	27	11	53,3	....	27	11	56
KHN...	143	6	3,2	....	143	6	14
	179	59	44,2		180	0	0

H N P.

HNP...	93	25	7,5	....	93	25	1
HPN...	37	22	2,1	....	37	21	56
NHP...	49	13	9,3	....	49	13	3
	180	0	18,9		180	0	0

N P Q.

NPQ...	87	52	24,3	....	87	52	17
NQP...	40	14	52,7	....	40	14	46
PNQ...	51	53	4,3	....	51	52	57
	180	0	21,3		180	0	0

STILL making uſe of

Toiſes.
$$AC = 8659{,}94$$

we have by the Reſolution of theſe laſt Triangles,

Toiſes.
$$QN = 13564{,}64$$
$$NK = 25053{,}25$$
$$KT = 16695{,}84$$

WHICH Lines make with the Meridian Line,

$$N\mathcal{Q}d = 78^{\circ}\ 37'\ 6''$$
$$KNL = 86\ \ 7\ \ 12$$
$$KTg = 85\ \ 48\ \ 7$$

THE Resolution of the Triangles *QNd*, *KNL*, *KTg*, gives for the parts of the Meridian Line,

		Toises.
	$N\,d =$	13297,88
	$K\,L =$	24995,83
	$K\,g =$	16651,05
	$\mathcal{Q}M =$	54944,76
The other Series gave . .	$\mathcal{Q}M =$	54940,39
Whence at a Mean . .	$\mathcal{Q}M =$	54942,57

CHAP.

CHAP. IV.

To determine the true Length of an Arc of the Meridian, its Amplitude being known.

I.

THE Places of our Obſervatories anſwering to the Centre of the Sector, when we made our Obſervations upon the fixt Stars, were that of *Torneå* more Southerly by 73 Toiſes, 4 foot, $5\frac{1}{2}$ inches, than the point *T*, (the Spire of the Church, and Vertex of our firſt Triangle); this diſtance was meaſured upon the Ice of the River by letting fall Perpendiculars: And that of *Kittis* more to the North than the Centre of our Signal *Q*, by 3 Toiſes, 4 foot, 8 inches. Fig. 2.

ADDING then to *QM*, theſe two diſtances, we have $qm = 55020{,}09$ Toiſes.

II. THIS

II.

THIS Line $q\,m$ is not precisely the Arc of the Meridian answering to the difference of Latitude.

FOR the perpendicular $t\,m$ is not the Arc of the Parallel that passes through t: Supposing the Arc $t\,\mu$ to be this Parallel, to find the point μ, draw the Tangent $t\,\nu$, and divide the distance $m\,\nu$ equally.

TO find the Value of $m\,\nu$, first compute the length of $m\,t$, in the present case nearly equal to $M\,T$, which, by the Resolution of the foregoing Triangles, will be found to be 3149,5 Toises: From this Line found, and the Latitude of *Torneå* given, supposing likewise (which can here occasion no sensible Error) that the Earth is spherical, and that a Degree contains 57000 Toises; the Angle made by the Tangents of the two Meridians that pass through Q and T, that is the Angle $m\,t\,\nu$, will easily be found to be 7'. 24". Whence $m\,\nu$ is 6,76 Toises, and its half 3,38 Toises $= m\,\mu$, added to the distance $q\,m$, gives for the Arc of

of the Meridian, whoſe Amplitude was obſerved, $q\,\mu = 55023{,}47$ Toiſes.

CHAP. V.

Obſervations to determine the Amplitude of the Arc of the Meridian, terminated by the Parallels that paſs through Kittis *and* Torneå.

I SHALL not at preſent give a compleat Deſcription of the Inſtrument we made uſe of; that would carry me too far, and is reſerved for another Work. I ſhall endeavour only to explain what is peculiar to this Inſtrument, and give my Readers ſuch a Notion of it as may enable them to underſtand the tryals we made of its goodneſs as well as the Obſervations themſelves.

A Braſs Teleſcope, of a conſiderable thickneſs, and about nine foot long, forms the Radius of a Limb of $5^\circ\frac{1}{2}$. This Limb has upon it two Diviſions, both of them from $7'\frac{1}{2}$ to $7'\frac{1}{2}$; the one to a ſhorter Radius,

marked

marked with greater points; the other to a longer Radius marked with ſmaller. At the Focus of the Teleſcope two Silver Wires croſs each other; Mr. *Graham* himſelf had fixt them in the firmeſt manner; and contrived, by means of two Springs, to keep them always in the ſame degree of tenſion, that they may not be ſubject to the leaſt Alteration. This Teleſcope, the Centre to which the Plumb-line is hung, and the Limb, are all one piece, and properly make up the whole Inſtrument; which will not therefore be ſo readily put out of order as one whoſe Centre can be taken off. It is ſuſpended by by two cylindric Pins, that reſting upon two Braſs Supports, allow it to ſwing freely like a Pendulum. One of the Pins ends in a very ſmall Cylinder; which is ſtill more diminiſhed where it meets the plane of the Limb, whoſe Centre it is. At this point of the Axis of the Pin is ſuſpended the Plummet. And round the ſame Axis the Teleſcope moves; while its Limb, by the means of two Wheels, ſlides along another immoveable Limb, which is fixt to a large Beam that paſſes through the middle of a great wooden Pyramid that ſupports the Inſtrument. To the immoveable Limb is

fixt

fixt the Micrometer, at the place moſt convenient for the Obſervation that is to be made. The uſe of the Micrometer is as follows:

THE immoveable Limb, and that of the Sector being placed in the Plane of the Meridian, the Teleſcope, as it hangs upon its Pins, would reſt in a vertical Situation. But a ſmall weight hung upon a Thread that paſſes over a Pulley, draws it Southward: While the Micrometer puſhes it the contrary way, by means of a point of Steel that reſts againſt a piece of hard poliſht Steel, fixt upon the Teleſcope. The motion of this Point towards the Mirror or from it, is regulated by a very fine Screw; making the Teleſcope deſcribe ſmall Arcs; while two Indexes mark the number of Revolutions, with the parts of a Revolution, by which the Point has advanc'd or retir'd. Theſe Revolutions meaſure then the Amplitude of the Arc obſerved, provided it is known how many Minutes and Seconds anſwer to one Revolution, by which the Point of the Micrometer goes backward or forward.

THE

THE proportion of the Number of Revolutions to the Arcs muſt vary as the place where the Point reſts upon the Speculum is higher or lower; and therefore on a Plate of Braſs that covers the Speculum when it is not made uſe of, there is drawn a Line marking where the Point of the Micrometer ought to reſt, ſo as to make the Revolutions of a determinate proportion to the Arcs. You may place the Point higher and lower till you get it exactly upon the Line: And then you have the ſituation of the Micrometer, upon which the Proportion is regulated.

IN obſerving, the firſt thing we did was to place exactly under the Thread of the Plummet that point of the Limb which was neareſt to where we knew the Plummet muſt cut in the time of Obſervation, the Ball of the Plummet being in the mean time immerſed in a Veſſel fill'd with Brandy. And this can be done to ſuch an Accuracy, by the help of the Micrometer and a Microſcope, on whoſe Focus the Light ſtrikes perpendicularly to the Limb, that placing and diſplacing the Thread ſeveral times,

times, you will rarely find one Diviſion of the Micrometer, that is to ſay, one Second of Difference. When the Thread, inſtead of hanging freely, reſted upon Pegs, as in the tryals we made for verifying the Inſtrument, we ſeldom had more than $\frac{1}{4}$ of a Second's Difference between one placing and another. An Accuracy which may ſeem incredible to ſuch as have never ſeen an Inſtrument like ours; but they will be better able to judge of it when they have conſidered the Obſervations made with it by ſo many different Perſons.

BEFORE the Star was to paſs the Meridian, we wrote down the Diviſion which was marked by the Micrometer, when the Thread exactly cut the Point upon the Limb. And juſt as the Star paſt the Meridian, the Obſerver, without being able to ſee the Micrometer, turned the Skrew, till he ſaw the Star biſſected in the Teleſcope, by the Thread that is perpendicular to the Limb. Then we reckoned how many Revolutions and Parts of a Revolution the Screw had made. And theſe added to the Arc terminated by the Point which the Plummet cut before the Obſervation, or

ſubtracted from it, gave the Point of the Limb where the Plummet muſt have cut when the Star paſſed the Meridian. And laſt of all, we verified the Obſervation by replacing the Point under the Thread, as it had been before the paſſage of the Star. If the Micrometer marked ſtill the ſame Revolution as it had marked before the Paſſage, or if the difference was but one or two Diviſions, then the Obſervation was held as good. And we took the Mean between the two Numbers of the Micrometer, before and after the Obſervation, for the true Number which it marked when the Point of the Limb was exactly under the Thread. But if the difference of theſe two Numbers was more than two Diviſions, we concluded that the Inſtrument muſt have been diſturbed ſome how, and that the Obſervation was not to be depended upon.

THE two Stars which we obſerved with this Inſtrument paſt the one within leſs than $\frac{1}{2}$ Degree from the Zenith of *Kittis*, and the other not $\frac{1}{4}°$ from that of *Torneå*. A Situation which might render us very ſecure as to any Errors ariſing from a wrong poſition of the Sector; which in other caſes,

if great care is not taken, may be very considerable. We knew that the misplacing it by several Minutes could have no sensible Effect upon our Observations; yet we placed it most exactly by a Meridian Line which we had drawn, and verified its position by the passage of some Stars whose heights we had taken.

II.

Observations of the Star δ *of the* Dragon *made with the Sector upon* Kittis, *for determining the Amplitude of the Arc of the Meridian.*

The 4th of October, 1736.

BEFORE the Observation of the passage of the Star in the Meridian, the Thread of the Plummet having been placed upon the point of the Limb marked 2°. 37′. 30″. of the upper Division, which we always made use of, the Micrometer marked	Revol. 24	10,7 parts, whereof 44 go to a Revol.
IN the time of Observation, that is, when the Star was passing the Meridian, the Micrometer marked . .	22	30,9

	Rev.	part.
AFTER the Obſervation the ſame Point 2°. 37′. 30″. being replaced under the Thread, the Micrometer marked	24	12,5
THE Mean of what the Micrometer marked before and after the Paſſage is . .	24	11,6
AND ſubtracting	22	30,9
RESTS, in parts of the Micrometer, the Arc between the point 2°. 37′. 30″. and that where the Thread had cut when the Star was in the Meridian, *viz.*	1	24,7

		Rev.	part.
5 Oct.	Before the Obſerv. . .	24	13,3
	In the time of Obſerv.	22	31,4
	After	24	15,3
		24	14,3
		22	31,4
	Difference	1	26,9

6 Oct.

		Revol.	part.
6 October	Before the Obſerv. . .	24	9,8
	In the time of Obſerv.	22	28,2
	After	24	9,8
		24	9,8
		22	28,2
	Difference	1	25,6
8 October	Before the Obſerv. .	18	1,0
	In the time of Obſerv.	16	16,7
	After	17	43,0
		18	0
		16	16,7
	Difference	1	27,3
10 Octob.	Before the Obſerv. .	17	33,0
	In the time of Obſerv.	16	8,3
	After	17	33,1
		17	33,0
		16	8,3
	Difference	1	24,7

THESE Obſervations were made by Day-light, without artificially illuminating the Focus of the Teleſcope.

III.

Observations of the same Star made at Torneå.

1736.

THE Thread of the Plummet cutting the Point of the Limb marked 1°. 37′. 30″. of the upper Division ;

The Micrometer marked,

		Rev.	parts.
1 Nov.	Before the Observ. . . .	17	39,5
	In the time of Observ. .	19	36,3
	After	17	40,5
		17	40,0
		19	36,3
	Difference	1	40,3
2 Nov.	Before the Observ. . . .	18	13,1
	In the time of Observ. .	20	8,8
	After	18	12,0
		18	12,5
		20	8,8
	Difference	1	40,3

3 Nov.

		Rev.	parts.
3 Nov.	Before the Obſerv.	18	37,0
	In the time of Obſerv. . .	20	33,3
	After	18	35,0
		18	36,0
		20	33,3
	Difference	1	41,3
4 Nov.	Before the Obſerv. . . .	18	32,2
	In the time of Obſerv. .	20	28,4
	After	18	31,0
		18	31,6
		20	28,4
	Difference	1	40,8
5 Nov.	Before the Obſerv.	12	24,4
	In the time of Obſerv. .	14	20,5
	After	12	24,0
		12	24,2
		14	20,5
	Difference	1	40,3

THESE Obſervations were likewiſe made by Day-light.

CHAP. VI.

Calculation of the Arc of the Meridian which we had obſerved.

	Rev.	parts.
The Obſervations upon *Kittis* give	1	24,7
	1	26,9
	1	25,6
	1	27,3
	1	24,7
Whoſe Mean is	1	25,8
The Obſervations at *Torneå* give	1	40,3
	1	40,3
	1	41,3
	1	40,8
	1	40,3
Whoſe Mean is	1	40,6

	°	′	″		Rev.	parts.
WE have then for the Arc of the Limb which the Thread cut as the Star paſſed the Merid. at *Kittis*	2	37	30	—	1	25,8
AND for the like Arc at *Torneå*	1	37	30	+	1	40,6

WHOSE

WHOSE difference is that of the Star's distance from the Zeniths of *Kittis* and *Torneå*, viz.	° ′ ″ 1 0 0	Rev. parts. —3 22,4

TO reduce the Revolutions and Parts of the Micrometer into Minutes and Seconds, it is to be noticed (vid. *infra*) that 15′ = 20 Rev. 23,5 Parts, whence . . .

	R. P. 3 22,4	= ′ ″ 2 33,8
Which taken from . .		° ′ ″ 1 0 0
give the Arc observed .		° ′ ″ 0 57 26,2

FURTHER, by the Construction of the Sector, the Chord of $5^{\circ}\frac{1}{2}$, which is 10,625 Inches *English*, is too little for the Radius, which is 110,75 by 0,002; that is, by $3''\frac{3}{4}$; which $3''\frac{3}{4}$ upon $5^{\circ}\frac{1}{2}$ give for $57'\frac{1}{2}$ the

K 4 pro-

proportional part to be ſubtracted, ...	0″,65
leaving for the Arc obſerved, ...	57′ 25″,55

PART

PART II.

Containing Verifications of the whole Work.

CHAP. I.

Verification of the Horizontal Angles by their Sum round the Heptagon.

	°	′	″	
CTK	24	22	54,5	Fig. 1.
KCT	37	9	12,0	
KCH . . .	100	9	56,8	
HCA	30	56	53,4	
CAH	112	21	48,6	
HAP	53	45	56,7	
APH	31	19	55,5	
HPN	37	22	2,1	
NPQ	87	52	24,3	
PQN	40	14	52,7	
QNP	51	53	4,3	
PNH	93	25	7,5	
HNK	27	11	53,3	
NKH	9	41	47,7	
HKC	43	45	35,6	
CKT	118	28	12,0	

THEIR Sum 900 1 37, exceeds by 1′. 37″, what it should be if the Figure lay

lay in a plane Surface, and if there was no Error in the Obſervations; it ought indeed to be a little more than 900, becauſe of the Earth's Convexity.

CHAP. II.

Vertification of the Heptagon, made at Torneå.

Fig. 4. THE Centre of the Quadrant of two foot Radius being placed in the Line paſſing through the *Spire* of the Church and the Signal of *Niwa*, we took the Angle which the horizontal Sun made with the Signal of *Niwa*, marking the time by a Clock which we had carried to the higheſt place of the Iſle *Swentzar*, and whoſe Hour we compared ſeveral times, by means of Signals, to that of a well-adjuſted Pendulum in the Houſe where I lodged.

1737, *the* 24*th of* May *at Night.*

True Time.

At 9^h 55$'$ 16$''$...nCS...13° 36$'$ 26$''$ = THE Angle between the Signal of *Niwa* and the Centre of the Sun, concluded from the Passage of his two Limbs by the vertical Wire in the Telescope.

SUPPOSING the Sun's Declination to be 20°. 53′. 29″,7, and the Latitude of the place of Observation 65°. 51′. 0″. *RCS* is found = 28°. 55′. 48″, The Angle of the Vertical of the Sun with the Meridian Line for the moment of Observation; from which subtracting *nCS* already found (13° 36$'$ 26$''$), remains *RCn* or *RTn* = 15 19 22 for the Angle which the Meridian Line forms with a Line joining the Spire of *Torneå* and the Signal of *Niwa*.

1737, *the* 25*th of* May, *in the Morning.*

THE Centre of the Quadrant placed in the direction of *Kakama* and the Spire of *Torneå.*

True Time.		
Fig. 5. At 2^h 3′ 5″	nCS..44° 6′ 34½″	THE Angle between the Signal of *Niwa* and the Centre of the rising Sun.
	nCK..19 52 34	THE Angle observed at the same place between the Signals of *Niwa* and *Kakama.*
	KCS..24 14 0½	ANGLE between the Signal of *Kakama* and the Sun.
	RCS..28 32 48	THE Angle of the Vertical of the Sun, with the Meridian calculated for the Moment of Observation, the Sun's Declination being 20°. 55′. 22″.

KCR

KCR, or *KTR*... $4^\circ\ 18'\ 47\frac{1}{2}''$	The Angle which the Meridian Line makes with a Line joining the Spire and the Signal of *Kakama*.

1737, *the 25th of* May, *in the Morning.*

The Quadrant being in the ſame Situation.

True Time.

At $2^h\ 9'\ 38''$...*nCS*...$45^\circ\ 36'\ 34\frac{1}{2}''$
nCK...19 52 34

KCS...25 44 $0\frac{1}{2}$ The Sun's
RCS...30 2 25 Declin. being
$20^\circ\ 55'\ 25''$.

KTR.. 4 18 $24\frac{1}{2}$ The Angle which the Meridian Line makes with a Line joining the Spire of *Torneå* and the Signal of *Kakama*.

Reducing the Poſition of *Niwa*, given from the former Obſervation, to that of *Kakama*, by the Angle *nTK*, which (pag. 105) is $19^\circ\ 38'\ 17'',8$, we ſhall have *KTR* .... 4 18 56 for the Declination of *Kakama*. Fig. 4 and 5.
And taking the Mean of theſe three Obſervations,

$$\left.\begin{array}{lll} 4^\circ & 18' & 24\frac{1}{2} \\ 4 & 18 & 47\frac{1}{2} \\ 4 & 18 & 56 \end{array}\right\}$$ we have $4^\circ\ 18'\ 42''\frac{1}{2}$ for the Declination of *Kakama* to the East.

But we had found from the Calculation of the Triangles, this Angle to be	4°	11′	53″
to which adding for the Convergence of the Meridians of *Torneå* and *Kittis* (found pag. 122.)	0	7	24
We ſhall have *KTR* . . = ...	4	19	17
By the three preceeding Obſervations, it was	4	18	42½
the Difference being	0	0	34½

too ſmall to be looked upon as any real Deviation of the Meridian Line: and accordingly we made no account of it; the rather becauſe the Figure's Poſition had been determined upon *Kittis* by a greater number of Obſervations.

CHAP.

CHAP. III.

Verification of the Distance of Torneå *from* Kittis, *by ten new Series of Triangles.*

I.

BY the Triangles *TnK*, *nKC*, *CKH*, *HCA*, *AHP*, *PHN*, *NPQ*. Fig. 6.

BEGINNING always from the Side *AC*, the Resolution of these Triangles gives for the Distance *QM* . . . . 54941 toises,
Which differs from 54942,57
found above (pag. 120.) by our
first two Series of Triangles, by. . . . $1\frac{1}{2}$

II.

BY the Triangles *TnK*, *KHn*, *nCH*, *HCA*, *APH*, *HNP*, *PNQ*; *QM*= 54936 Fig. 7.
Less than *QM* (pag. 120.) by . . . . . . $6\frac{1}{2}$

III.

BY the Triangles *TnK*, *KnH*, *HnA*, Fig. 8.

 ACH,

ACH, *HAP*, *PHN*, *NPQ*; $QM = 54942\frac{1}{2}$
The difference being insensible.

IV.

Fig. 9. BY the Triangles *TnK*, *KCH*, *HnC*, *CHA*, *AHP*, *PHN*, *NPQ*; $QM = 54943\frac{1}{2}$
The difference being 1

V.

Fig. 10. BY the Triangles *TnK*, *KnC*, *CnA*, *ACH*, *HAP*, *PHN*, *NPQ*; $QM = 54925$
The difference being . . . . $17\frac{1}{2}$

VI.

Fig. 11. BY the Triangles *TnK*, *KnH*, *HAn*, *nCA*, *AHP*, *PHN*, *NPQ*; $QM = 54915\frac{1}{2}$
The difference being 27

VII.

Fig. 12. BY the Triangles *TnK*, *KnC*, *CAn*, *nHK*, *KHN*, *NHP*, *PNQ*; $QM = 54912$
The difference being . . . . $30\frac{1}{2}$

VIII.

Fig. 13. BY the Triangles *TnK*, *KCn*, *nAC*, *CHK*, *HKN*, *NHP*, *PNQ*; $QM = 54906\frac{1}{2}$
The difference being 36

IX.

IX.

BY the Triangles *TnC, CnA, AnH,* Fig. 14.
HAP, PHN, NPQ; QM. = 54910
The difference being 32½

X.

BY the Triangles *TnC, CAn, nCK, KnH,* Fig. 15.
HKN, NHP, PNQ; QM = 54891½
The difference being . . . . 51½.

THOUGH the differences arising from so many Series are none of them very considerable, yet we did not think fit to admit them into the Determination of the length of our Arc, but used two others which we judged preferable.

CHAP. IV.

Another Verification of the Distance between Tornea *and* Kittis.

ALTHOUGH from these ten Series, it sufficiently appears that no material Error could have crept into our Observations of the Triangles, seeing none of these Fig. 16.

Combinations, though ſome of them contain Triangles that might be rejected for the ſmallneſs of their Angles, produce any conſiderable Difference; yet we have added another Verification, which would take off all ſuſpicion of that kind, even though we had obſerved no more than the Angles neceſſary for the firſt Series.

WE ſuppoſe as if we had in two of the Angles of every Triangle, miſtaken by 20″, and by 40″ in the third; and that theſe Errors had always tended to ſhorten the Meridian Line *QM*. The ſmall difference which riſes from this Suppoſition proves the advantage we had from our Triangles being ſo few, and from the Poſition of the Baſe with reſpect to them. The Calculation is after this manner:

BEGINNING always from the Baſe *Bb*, and making the Angles *Bba* and *bBa*, leſs than *BbA* and *bBA* by 20″, you find the Side *aB* inſtead of *AB*. Then making uſe of this Side *aB*, and making the Angles *BaC*, and *aBc*, leſs by 20″ than *BAC*, *ABC*, you find the Point *c* inſtead of *C*, and the Side *ac* inſtead of *AC*.

FROM

FROM *ac*, you find the Sides *ab* and *cb* instead of *AH* and *CH*, supposing the Angles *cab*, *acb*, less than *CAH*, *ACH* by 20″ respectively. And proceeding still in the same manner in diminishing the Triangles, you come to have the Figure *qpnhackt* instead of *QPNHACKT*.

THEN supposing likewise an Error of 20′ in the Position of the Meridian Line, that is, supposing *pqm* less by 20′ than *PQM*, you find after the most exact Calculation *qm* less than *QM* by no more than 54 toises; a difference very inconsiderable to result from such a strange Supposition of bad Luck and unskilful Observation.

CHAP. V.

Verification of the Amplitude of the Arc of the Meridian.

I.

Obſervations of the Star α *of the* Dragon, *made at* Torneå, *in the ſame place where we had obſerved* δ.

1737.

THE Plummet cutting the Point of the upper diviſion of the Limb marked 3° 15′, the Micrometer ſtood at

		Revol.	part.
17 *March.*	Before the Obſerv. . . .	19	32,7
	In the time of the Obſ. .	16	42,0
	After	19	34,0
		19	33,3
		16	42,0
	Difference.	2	35,3

		Revol.	part.
18 *March.*	Before the Observ. . . .	22	21,6
	In the time of the Obs. .	19	30,4
	After	22	21,9
		22	21,7
		19	30,4
	Difference	2	35.3
19 *March.*	Before the Observ. . . .	21	21,0
	In the time of the Obs.	18	32,1
	After	21	21,3
		21	21,1
		18	32,1
	Difference	2	33,0

II.

Observations of the same Star made upon Kittis, *in the same place where we had observed* δ.

1737.

THE Plummet cutting the Point of the upper Limb that is marked 4° 15′ 0″.

The Micrometer stood at

4 *April.*	Before the Observ. . . .	21	12,0
	In the time of the Obs. .	14	43,0
	After	21	12,0
		21	12
		14	43
	Difference	6	13,0

		Revol.	Part.
5 *April.*	Before the Obſerv. . . .	21	12,5
	In the time of the Obſ. .	15	0,0
	After	21	12,2
		21	12,3
		15	0,0
	Difference	6	12,3
6 *April.*	Before the Obſerv. . .	21	19,5
	In the time of the Obſ. . .	15	7,2
	After	21	19,7
		21	19,6
		15	7,2
	Difference	6	12,4

THESE Obſervations both at *Torneå* and *Kittis*, were made by the Light of a Torch thrown by Reflection upon the Focus of the Teleſcope.

CHAP.

CHAP. VI.

Calculation of the observed Arc of the Meridian.

	Revol.	part.
THE Observations of *Torneå* give . .	2	35,3
	2	35,3
	2	33,0
And at a Mean . .	2	34,5

Those of *Kittis* give . . .	6	13,0
	6	12,3
	6	12,4
And at a Mean . .	6	12,6

WHENCE we have for the Arc of the Limb which the Plummet cut at the Star's Passage . . . . . $3^{\circ}\ 15'\ 0''$—2 34,5 (Revol. part.)

And for the like Arc upon *Kittis* . . 4 15 0—6 12,6

The difference of which two Arcs, that is the difference of the Star's distances from the Zeniths of *Torneå* and *Kittis* is	° ′ ″ Revol. part. 1 0 0—3 22,1
But 3 Rev. 22,1 pt.	2′ 33″,5
which ſubtracted from . . .	1° 0 0
leaves for the Arc obſerved . .	57 26,5
which the Correction on account of the Chord of 5° ½ its being too ſmall, *viz.*	0° 0 0,65
reduces to	57 25,85

CHAP. VII.

Verifications of the Sector.

I.

Verification of the whole Arc of 5° ½.

AT *Torneå*, the 4th of *May*, 1737, we meaſured upon the Ice of the River a diſtance of 380 toiſes, 1 f. 3 inches, 0 line: it was meaſured twice over; and between the firſt and ſecond time, there was not the leaſt dif-

difference. At one Extremity of this distance was placed the Centre of the Instrument, which was laid horizontally upon two great Supports, in a Room we had chose for that purpose, by the River-side: at the other Extremity was raised a Post, with a *Mark* upon it; from whose Centre in a Line perpendicular to the first measured distance, which was to serve for a Radius, we laid out 36 T. 3 f. 6 in. $6\frac{2}{3}$ lin. for our Tangent, which was terminated at the Centre of a *Mark* fixed upon another Post. This formed upon the Ice a Sector of about 380 toises Radius, with which we were to compare ours.

FROM the Centre of the Instrument we had stretched a Silver Wire to a fixt Point, which by trials we had found to be altogether immoveable, so as when the Sector turned horizontally upon its Centre, the Wire only not touched its Limb.

THE Angle between the two Marks taken by five different Persons, exceeded $5^{\circ}\ 30'$, as follows:

Parts

	Parts of the Microm.
1ſt. by . . .	6,5
2d. by . . .	8,3
3d. by . . .	7,0
4th. by . . .	7,9
5th. by . . .	6,8
Whereof the Mean is . .	7,3, or 7″,3.

NOW according to the Conſtruction of the Sector (pag. .) our Arc was too ſmall by 3″¾:

whence from . .	5°	29′	56″,25
taking			7,3
reſts the true Angle obſerved	5	29	48,95
And the ſame Angle is by Calcul.	5	29	50,00

Which ſhews the exquiſite Conſtruction of this Inſtrument, and what Accuracy may be expected from it. For this difference of 1″ upon an Arc of 5°½, which might come from the Errors in obſerving, is altogether inconſiderable.

II.

II.

Verification of the two Degrees which we used in determining the Amplitude.

THE Sector remaining in the same horizontal Position, we extended from its Centre two small *Wires*, making with each other an Angle very nearly equal to 1°; these Wires only not touched the Limb, and were fixed by two immoveable Pegs: over each of them we placed a Microscope, whose Focus was illuminated by the light of a Wax Candle, collected by a Lens; and as the Micrometer made the Telescope move, all the Points of the Limb passed successively in the Foci of the Microscopes.

IN this manner we compared with the fix'd Interval of the Threads, the two Degrees which we had made use of for the two Stars, making them pass under the threads by turns; and from five Observations made by different Persons, found that the Degree between 1° 37′ 30″, and 2° 37′ 30″, exceeded that between 3° 15′ 0″, and 4° 15′ 0″.

The

The Excefs was,

By the 1ſt Obſerv.	. . .	0″,6	
2d	. . . . .	0, 7	
3d	. . . . .	0, 8	} 0″,95
4th	. . . . .	0,85	
5th	. . . . .	1, 8	

WHENCE at a Mean, the Arc uſed for determining the Amplitude by the Star δ was greater than that uſed for determining it by α, by 0″,95.

THIS ſmall difference of the two Degrees on the Limb, we ought to reckon upon quite otherwiſe than upon that of the preceeding Article. That depended not only upon the Obſervation of the Point under the thread, but upon the Obſervation of an Object with the Teleſcope; whereas here we had only to place the point exactly under the thread; which, with a Microſcope well lighted, may be performed to the utmoſt nicety.

III.

Verification of the Diviſions of the Sector.

WE examined in the ſame manner every diviſion of the Limb from 15′ to 15′; and have

have marked the result in the following Table, which shews the Exactness both of the Divisions and of the Micrometer.

	according to us.		*accor. to Mr.* Graham.
° ′ ° ′	Revol.	part.	part.
From 0 15 to 0 30	20	23,2	22,75
0 30 to 0 45		22,2	22,25
0 45 to 1 00		23,7	23,5
1 00 to 1 15		23,4	23,75
1 15 to 1 30		24,3	24,5
1 30 to 1 45		23,2	23,5
1 45 to 2 00		23,8	24,5
2 00 to 2 15		23,4	23,875
2 15 to 2 30		23,1	23,5
2 30 to 2 45		23,6	24,125
2 45 to 3 00		23,3	23,5
3 00 to 3 15		24,3	24,375
3 15 to 3 30		24,0	24,0
3 30 to 3 45		23,1	23,25
3 45 to 4 00		24,0	24,125
4 00 to 4 15		23,4	24,125
4 15 to 4 30		22,9	23,75
4 30 to 4 45		23,3	23,5
4 45 to 5 00		22,9	22,75
5 00 to 5 15		23,6	24,25
5 15 to 5 30		23,0	23,625
5 30 to 5 45		22,1	22,5
The Mean gives 15′ =	20R.	23,3p.	23,6p.

CHAP.

CHAP. VIII.

Determination of the Degree of the Meridian which cuts the Polar Circle.

I.

Determination of the Amplitude of the Arc of the Meridian, terminated by the Parallel Circles which paſs through Kittis *and* Torneå.

THE Amplitude of the Arc of the Meridian as determined by the Star δ, was by Obſervation (p. 136.) . . 57′ 25″,55.

AND the ſame Amplitude as determined by α, was by Obſervation . . . 57′ 25″,85.

TO find the true Amplitude which the one and the other of theſe Stars gives, we muſt correct the Arcs as follows:

FOR THE STAR δ.

BY the Preceſſion of the Equinoxes from the 6th of *October* to the 3d of *November*, which

which we take for the Interval of the Obſervations of δ, this Star was come nearer the Pole by 0″,48; and the Star having been to the North of *Kittis*

from the Arc obſerved	57′ 25″,55
ſubtracting this quantity . . .	0,48
there will remain the *Amplitude corrected for the Preceſſion*, viz. . .	57 25,07

BY the Aberration of the Star's Light in the ſame Interval, it was ſeen farther from the Pole by . . .	1,83
which added, gives for the *Amplitude corrected for both the Preceſſion and Aberration*	57 26,9

FOR THE STAR α.

BY the Preceſſion of the Equinoxes from the 18th of *March* to the 5th of *April*, the Interval of the Obſervations of α, this Star was farther from the Pole by 0″,85; and having been ſeen to the South of *Torneå*, from

the Arc obſerved (p. 152.) *viz.* . .	57′ 25″,85
ſubtracting	0, 85
we have for the *Amplitude corrected for the Preceſſion* . . .	57 25,00

BY

BY the Aberration of this Star's light in the same time, it appeared nearer the Pole by . . . . . 5″,35

which added, gives for the Amplitude as determined by α, *corrected both for the Precession and the Aberration* . . . 57 30,35

II.

A more exact Determination of the same.

Mr. *Bradley* having been pleased to send me his last Discoveries upon the Motion of the fixt Stars, as likewise Corrections of the two Arcs determined by δ and α, not only for the *Precession* of the Equinoxes and *Aberration* of Light, but for that *third Motion* mentioned above ; I shall here, for the greater accuracy, apply his Corrections as they were sent me, though they do not sensibly differ from those just now made.

To the Arc observed by δ (p. 136.)	57′	25″,55
add	0	1,38
And you have the Amplitude by δ *corrected for all the Motions,* viz. .	57	26,93

To

To the Arc observed by α (p. 152.)	57′ 25″,85
add	0 4,57
and you have *the Amplitude by* α, *corrected for all the Motions* . . .	57 30 42

THOUGH the difference between these two Amplitudes is no more than 3″,49, it appears, from pag. 156, that it is really but 2″,54: and it would not amount even to 2″, if only the best of the Observations were used; these, where the Micrometer after the Star had past the Meridian, upon replacing the Point under the thread, stood at within 1″ or less of what it had mark'd before. This difference is so small, that there is no doubt left of the Accuracy of the Operations.

I make no allowance for Refraction; for if there is any at all so near the Zenith, it must be imperceptible, and cannot effect the present Case.

III.

Determination of the Degree of the Meridian which cuts the Polar Circle.

WE shall then take for the true Amplitude of the Arc of the Meridian between the

Parallels of *Kittis* and *Torneå*, 57'. 28",67 being a Mean betwixt the two foregoing. And this Amplitude, compared with the length of the Arc $q\,\mu$, which (*page* 123.) is 55023,47 Toiſes, gives for the *length of the Degree of the Meridian which cuts the Polar Circle* 57437,9 *Toiſes.*

IV.

Remark upon the Degree meaſured by M. Picard.

THIS Degree is longer by 377,9 than that which paſſes commonly for the Mean Degree of *France*, rated by M. *Picard* at 57060 Toiſes. But if M. *Picard*'s Degree is corrected by making the proper Allowances, firſt for the *Aberration* of Light of the Star δ in *Caſſiopeia*'s *Knee*, by which he determined his Amplitude, taking for the middle times of his Obſervations the 15th of *September*, and the 15th of *October*, there will be, on this account, 8"$\frac{1}{2}$ to be added to the Amplitude of the Arc between *Malvoiſine* and *Amiens.* And if there is further added 1"$\frac{1}{2}$ for the *Preceſſion* of the Equinoxes, and 1"$\frac{1}{2}$ for the *Refraction*, all which he had neglected, his Amplitude will become

1°.

$1^{\circ}.23'.6''\frac{1}{2}$. And comparing it with his Arc of 78850 Toiſes, the Degree of the Meridian near *Paris* will be 56925,7 Toiſes, ſhort of ours by 512,2.

IN fine, If Mr. *Bradley*'s Theory is ſet aſide, and the Stars are ſuppoſed to have no other Change of Declination but what ariſes from the Preceſſion of the Eqinoxes, our Amplitude by the Star δ (*page* 159.) would be $57'.25'',07$, and by the Star α (*ibid.*) $57'.25'',00$. Whence our Degree would be ſtill longer than it is in Mr. *Bradley*'s Hypotheſis.

V.

CONCLUSION.

THE Degree of the Meridian which cuts the Polar Circle being longer than a Degree of the Meridian in France, *the Earth is a Spheroid flatted towards the Poles.*

CHAP. IX.

A Method to determine the Figure of the Earth from the Lengths of two Degrees of the Meridian.

IF the Length of two different Degrees of the Meridian is meaſured at two different places of known Latitudes, the Figure of the Earth may be determined: Of which Problem you have the following Solution; with a Formula expreſſing the Proportion of the Earth's Axis to the Diameter of the Equator.

Problem.

The Lengths and Latitudes of two Degrees of the Meridian being given, to find the Figure of the Earth.

Fig. 17. Conſidering the Earth as a Solid generated by the Revolution of an *Ellipſe* upon its Axis, from which it very little differs, let the Ellipſe PAp repreſent a Meridian, whoſe Axis is Pp, and the Diameter of the Equator

Equator *A a*. Let *E e*, *F ſ*, be two Degrees of this Ellipſe, or two little Arcs of the ſame Amplitude. The Perpendiculars to the Ellipſe at their Extremities will meet at points *G* and *H*, making the Angles at *G* and *H* equal. And the Latitudes of theſe two Arcs, or the Angles *EKA*, *FLA* are given.

LET *CP* be to *CA* as *m* to 1; *CM* $= x$, $EM = y$; the Sine of the Angle *EKA*, that is the Sine of the Latitude of the point *E*, $= ſ$: The Sine of *FLA*, or of the Latitude of *F*, $= s$, and the Radius 1. Put likewiſe the Arcs $Ee = E$, and $Fſ = F$.

BY the Property of the Ellipſe $y = m \times \sqrt{1 - x^2}$; $EK = m \times \sqrt{1 - x^2 + m^2 x^2}$; and the Radius of Curvature $EG = \frac{1}{m} \times \overline{1 - x^2 + m^2 x^2}|^{\frac{3}{2}}$ and the Expreſſions of *FL* and *FH* are the ſame for their correſpondent x's. Now the Sine of *EKA*, to the Radius 1, being $ſ$, $1 : ſ :: m\sqrt{1 - x^2 + m^2 x^2} : m\sqrt{1 - x^2}$, that is $x^2 = \frac{1 - ſſ}{1 - ſſ + m^2 ſ^2}$. Subſtituting this Value of x^2 in the Expreſſions of *EG* and

 FH,

FH, we have $EG = \dfrac{m^2}{\overline{1 - \text{ſ}^2 + m^2 \text{ſ}^2}|^{\frac{3}{2}}}$

and $FH = \dfrac{m^2}{\overline{1 - s^2 + m^2 s^2}|^{\frac{3}{2}}}$ And ſeeing the Arcs Ee, and Ff are of the ſame Amplitude, that is, ſeeing the Angles G and H are equal, $E : F :: \dfrac{m^2}{\overline{1 - \text{ſ}^2 + m^2 \text{ſ}^2}|^{\frac{3}{2}}} : \dfrac{m^2}{\overline{1 - s^2 + m^2 s^2}|^{\frac{3}{2}}}$ that is,

$$E \times \overline{1 + \overline{m^2 - 1} \times \text{ſ}^2}|^{\frac{3}{2}} =$$

$$F \times \overline{1 + \overline{m^2 - 1} \times s^2}|^{\frac{3}{2}}$$ Or, by extracting the Root,

$$E \times \overline{1 + \tfrac{3}{2} \times \overline{m^2 - 1} \times \text{ſ}^2 + \tfrac{3}{8} \times \overline{m^2 - 1}|^2 \times \text{ſ}^4 + \&c.}$$
$$= F \times \overline{1 + \tfrac{3}{2} \times \overline{m^2 - 1} \times s^2 + \tfrac{3}{8} \times \overline{m^2 - 1}|^2 \times s^4 + \&c.}$$

BUT the Spheroid of the Earth being very little different from a Sphere, the quantity $m^2 - 1$ is ſmall, and the Terms multiplied by its Square and its higher Powers may be neglected. Whence $E \times \overline{1 + \tfrac{3}{2} \times \overline{m^2 - 1} \times \text{ſ}^2}$ $= F \times \overline{1 + \tfrac{3}{2} \times \overline{m^2 - 1} \times s^2}$ that is,

$2E + 3 \times \overline{m^2 - 1} \times E \text{ſ}^2 =$

$2F + 3 \times \overline{m^2 - 1} \times F s^2$. Or $\overline{1 - m^2}$ $= \frac{2 \times \overline{E - F}}{3 \times \overline{E \text{ſ}^2 - F s^2}}$ Or putting D for the difference between the Semi-axe and the Semi-diameter of the Equator, it is $D =$ $\frac{E - F}{3 \times \overline{E \text{ſ}^2 - F s^2}}$ or $D = \frac{E - F}{3 E \times \overline{\text{ſ}^2 - s^2}}$ Whence the Species of the Spheroid may be eaſily determined, and a Table calculated of the Lengths of a Degree for every Latitude.

Coroll. IF one of the Degrees is taken at the Equator, the Equation is changed into $D = \frac{E - F}{3 E \text{ſ}^2}$ And if the other Degree is taken at the Pole, it is $D = \frac{E - F}{3 E}$ Whence it follows, That the Semi-Diameter of the Equator is to thrice the laſt Degree of Latitude, as the difference between the Semi-Diameter of the Equator and the Semi-Axis is to the difference between the firſt and the laſt Degree of Latitude.

OBSERVATIONS

Made at the Polar Circle.

BOOK II.

Containing Astronomical Observations for determining the Height of the Pole at Torneå, *the Refraction, and the Longitude.*

CHAP. I.

Observations of Arcturus, *and of the Pole-Star, at* Torneå *and at* Paris.

I.

Observations of Arcturus, *and the Pole-Star, at* Torneå.

WE observed the distances of the Pole-Star, and of *Arcturus* from the Zenith; at *Torneå* and *Paris,* in order to discover if, at the height of these Stars, the Refraction at *Torneå* was sensibly different from

from what it is at *Paris*; as the Obſervations of *Bilberg* at *Torneå*, and of the *Hollanders* in *Nova Zembla* gave ground to think.

WE had choſe theſe two Stars, becauſe the Arc of the Meridian terminated by their Parallels, was, at *Torneå*, nearly of the ſame height as at *Paris*, only in an oppoſite Situation. Whence, if the Refraction was greater at *Torneå*, this Arc muſt there appear ſhorter than at *Paris*.

BUT it is found by Obſervation to be very near of the ſame quantity at both theſe places. The little difference there was, made rather for leſſening the Refraction at *Torneå*; but this we aſcribe to the Errors of the Obſervations, which were not of Authority enough to eſtabliſh an Inequality of Refraction, at that height.

FOLLOW the Obſervations of theſe two Stars, made at *Torneå* with a Quadrant of three foot Radius, and at *Paris* with one of 2½; both well verified by back Obſervations.

Distance of the Pole-Star from the Zenith of Torneå.

Observed in *Novem.* and *Decem.* 1736.	°	′	″	Reduced for 1737. °	′	″
27 Novemb. . .	22	2	51 . .	22	3	11
29 Novemb. . .	22	2	40 . .	22	3	0
1 Decemb. . .	22	2	43 . .	22	3	3

Whence, at a Mean, the distance of the Pole-Star from the Zenith of *Torneå*, in the beginning of *December* 1737, 22 3 5

Distance of Arcturus *from the Zenith of* Torneå.

1736	°	′	″	°	′	″
26 Novemb. . .	45	15	49 . .	45	16	6
1 Decemb. . .	45	16	4 . .	45	16	21
3 Decemb. . .	45	15	43 . .	45	16	0
9 Decemb. . .	45	15	52½ .	45	16	9½

Whence

	°	′	″
Whence at a Mean, the distance of *Arcturus* from the Zenith of *Torneå* was, in the beginning of *December* 1737,	45	16	9
Which added to the distance of the Zenith from the Pole-Star	22	3	5
Gives for the Arc of the Meridian terminated by the Parallels of these two Stars, as observed at *Torneå*, ...	67	19	4

II.

Observations of the same Stars at Paris.

Distance of the Pole-Star from the Zenith of Paris.

Observed in *Novemb.* and *Decemb.* 1737.

	°	′	″
8 Novemb.	39	2	$19\frac{1}{2}$
9 Novemb.	39	2	22
5 Decemb.	39	2	30
8 Decemb.	39	2	33
14 Decemb.	39	2	34

Whence

Whence at a Mean, the distance of the Pole-Star from the Zenith of *Paris* was, in the beginning of *December* 1737, ...	39°	2′	8″

Distance of Arcturus *from the Zenith of* Paris.

	°	′	″
29 October 1737	28	16	30
8 November	28	16	32
16 December	28	16	44
24 December	28	16	43

Whence, at a Mean, the distance of *Arcturus* from the Zenith of *Paris* was, in the beginning of *December* 1737,	28	16	37
Which added to the distance of the Zenith from the Pole-Star	39	2	28
Gives the Arc of the Meridian terminated by the Parallels of these two Stars, as observed at *Paris*, ...	67	19	5

III. *The*

III.

The same repeated, upon Observations of the Pole-Star in the lowermost point of its Circle.

Distances of the Pole-Star from the Zenith of Torneå.

Observed in *Nov.* and *Decemb.* 1736.		Reduced for 1737.
	° ′ ″	° ′ ″
26 Novemb. . . .	26 14 37	26 14 17
27 Novemb. . . .	26 14 37	26 14 17
1 Decemb. . . .	26 14 36	26 14 16

Whence at a Mean, the distance of the Pole-Star from the Zenith of *Torneå* was, in the beginning of *December* 1737, ... 26 14 17

The distance of *Arcturus* (*page* 171.) was 45 16 9

Whence the Arc of the Meridian terminated by the Parallels of these two Stars, as observed at *Torneå*, is 71 30 26

IV. *Di-*

IV.

Distances of the Pole-Star from the Zenith of Paris.

Observed in *Novem.* and *Decem.* 1737.

	°	′	″
2 Decemb.	43	13	42
3 Decemb.	43	13	41
9 Decemb.	43	13	42
14 Decemb.	43	13	47
19 Decemb.	43	13	45
Whence at a Mean, the distance of the Pole-Star from the Zenith of *Paris* was, in the beginning of *December* 1737, ...	43	13	43
The distance of *Arcturus* (*p.* 172.)	28	16	37
Whence the Arc of the Meridian terminated by the Parallels of these two Stars as observed at *Paris*, is	71	30	20

V.

FROM which Observations it appears, that at the height of these Stars, the Refractions

fractions at *Torneå* and at *Paris* are not ſenſibly different.

BUT, independent of theſe Obſervations, we may firſt ſeek the height of the Pole at *Torneå*, ſuppoſing theſe Refractions to be equal, which at this height can cauſe no ſenſible Error; and then make uſe of the height of the Pole thus determined, to find the horizontal Refractions; which if they come out nearly the ſame as at *Paris*, we may thenceforth ſafely enough uſe the ſame Table of Refraction for the greateſt Altitudes at *Torneå*.

CHAP. II.

Height of the Pole at Torneå.

I.

Height of the Pole, from Observations made with the Quadrant of three foot Radius.

IN the beginning of *December* 1736, the least distance of the Pole-Star from the

	°	′	″
Zenith of *Torneå* was (*page* 170.)	22	2	45
the greatest (*page* 173.)	26	14	37
Their Sum . . .	48	17	22
Whose half . . .	24	8	41
is the distance of the Zenith of *Torneå* from the Pole, and its Compliment	65	51	19
will be the apparent height of the Pole. From which subtracting a Mean between the Refractions at *Paris*, as determined by Mr. *Cassini* and Mr. *de la Hire*, viz. . .	0	0	29
there remains	65	50	50

for the height of the Pole at *Torneå*, that is for the southermost point of the Arc which we measured.

II. *Height*

II.

Height of the Pole, from Obſervations made in the ſame Place with a Quadrant of two foot Radius.

The greateſt diſtance of the Pole-Star from the Zenith.	°	′	″	*The leaſt diſtance of the Pole-Star from the Zenith.*	°	′	″
				At *Torneå* 1737.			
6 Jan. . .	26	14	21	9 Jan. . .	22	3	2
7 Jan. . .	26	14	24	12 Jan. . .	22	2	57
				18 Jan. . .	22	2	54
				19 Jan. . .	22	3	0
This day the Quadrant had been verified by back-Obſervation.				22 Jan. . .	22	2	57
The *Means*	26	14	22½	. . . . . .	22	2	58

	°	′	″
Sum of theſe diſtances	48	17	20
whoſe half	24	8	40
is the diſtance of the Zenith of *Torneå* from the Pole, whoſe Complement	65	51	20
is the apparent height of the Pole; from which taking for the Refraction	0	0	29
remains the height of the Pole at *Torneå*	65	50	51

III.

A Remark.

ALTHOUGH theſe heights of the Pole in the two laſt Articles coincide, yet you may obſerve there is a difference of 14″ in the diſtance of the Pole-Star from the Pole, as there marked. Which makes me ſuſpect there have been ſome Errors in the Obſervations that have compenſated each other. This might be partly cauſed too, by the Preceſſion of the Equinoxes and the *Aberration* of Light, in the interval of the Obſervations.

WE may then take for the height of the Pole at *Torneå* . . . . . 65°. 50′. 50″. exceeding what *Bilberg* found it to be by 8′, and by 11′ what he ought to have found it, if he had made the proper Allowances for the obliquity of the *Ecliptic*, the *Parallax*, and *Refraction.*

AND ſeeing his Obſervations gave him an Altitude of the Pole ſo wide of the Truth, we need not wonder that he fell into ſtill greater Errors as to the *Refraction*; which

which has hitherto been imagined to be almost the double of what it is at *Paris.*

THE Amplitude of our Arc between

	′	″
Torneå and *Kittis* being (*p.* 162.)	57	28,7
the height of the Pole upon *Kittis* will be 66 48		18,7
for which we shall take . . . 66 48		20

CHAP. III.

Meridian Altitudes of the Sun.

I.

Meridian Altitudes of the upper Limb of the Sun, observed at Torneå, *at the extremity of our Meridian Line, with a Quadrant of three foot Radius,* 1736.

WE placed, in a little Observatory built on the River, the Instrument we had made use of at *Kittis* to determine the position of our Triangles with respect to the Meridian Line, (*vid.* p.109.)

THE Telescope of this Instrument moved about its Axis, exactly in the Plane of the Meridian; and if it chanced to be put out of this position, we restored it by means of an Object placed at about half a League's distance in the Meridian Line. The Altitudes were taken in the Moment the Sun past the Centre of this Telescope.

	°	′	″
26 November 1736.	3	35	23
27 November	3	24	30
1 December	2	45	42
3 December	2	31	0
8 December	1	56	51

II.

Meridian Altitudes of the Upper Limb of the Sun observed in the same place, with a Quadrant of two foot Radius, 1737.

	°	′	″
5 January 1737	2	9	32
7 January	2	24	33
9 January	2	37	26
12 January	3	4	26
13 January	3	15	23
19 January	3	21	29

ON

ON the 22d the Quadrant was verified by back-Obſervation, and afterwards uſed to take the horizontal Angles.

III.

Meridian Altitudes of the Sun's upper Limb at the vernal Equinox.

WE verified once more the Quadrant of three foot, and obſerved the following Meridian Altitudes of the upper Limb of the Sun.

	°	′	″
15 March 1737 . . .	22	26	16
16 March	22	50	12
17 March	23	13	50
18 March	23	37	9
21 March	24	47	11
22 March	24	11	35

CHAP. IV.

Determination of the Refractions.

I.

THE following Calculation supposes the height of the Pole, as found p.

THE finding the Refraction by the Meridian Altitudes of the Sun supposes likewise, to be given, the *Elevation of the Equator, the Obliquity of the Ecliptic, the Sun's Place, and his Parallax.*

I put the Elevation of the	°	′	″
Equator	24	9	10
the Obliquity of the *Ecliptic* . .	23	28	20

the Parallax according to Mr. *Cassini*; and the Sun's place, from Mr. *de Louville*'s Tables, reduced to the Meridian of *Torneå*, which we know to be nearly 1h. 23′ East of *Paris*. And an Error of a few Minutes can here be of no consequence, because, at the time of our Observations, the Sun's

daily

daily Change of Declination is inconsiderable.

II.

The 1st of Decemb. 1736, *at Noon.*

	°	′	″
The South Declination of the Sun at *Torneå*	21	55	21
The Eelvation of the Equator .	24	9	10
Whence the height of the Sun's Centre	2	13	49
The Parallax to be ſubtracted .	0	0	10
Leaves the true height of the Sun's Centre at *Torneå* . .	2	13	39
The Sun's Semi-diameter to be added	0	16	19
Gives the true height of the Sun's upper Limb	2	29	58
But the ſame height was by Obſervation	2	45	42
Whence the Refraction at the apparent height of 2°. 46′. is	0	15	44

III.

The 3d of Decemb. 1736, *at Noon.*

	°	′	″
The South Declination of the Sun at *Torneå*	22	12	46
The Elevation of the Equator .	24	9	10
Whence the height of the Sun's Centre	1	56	24
The Parallax to be subtracted .	0	0	10
Leaves the true height of the Sun's Centre at *Torneå* . . .	1	56	14
The Sun's Semi-diameter to be added	0	16	20
Gives the true height of the Sun's upper Limb	2	12	34
But the same height was by Observation	2	31	0
Whence the Refraction at the apparent height of 2°. 31′. .	0	18	26

IV. *The*

IV.

The 8th of Decemb. 1736, *at Noon.*

	°	′	″
The South Declination of the Sun at *Torneå*	22	48	33
The Elevation of the Equator .	24	9	10
Whence the height of the Sun's Centre	1	20	37
The Parallax to be ſubtracted . .	0	0	10
Leaves the true height of the Sun's Centre at *Torneå*	1	20	27
The Sun's Semi-diameter to be added	0	16	21
Gives the true height of the Sun's upper Limb	1	36	48
But the ſame height was by Obſervation	1	56	51
Whence the Refraction at the apparent height of 1°. 57′. . .	0	20	3

V. *The*

V.

The 5th of January 1737, *at Noon.*

	°	′	″
The South Declination of the Sun at *Torneå*	22	35	53
The Elevation of the Equator .	24	9	10
Whence the height of the Sun's Centre	1	33	17
The Parallax to be subtracted . .	0	0	10
Leaves the true height of the Sun's Centre at *Torneå*	1	33	7
The Sun's Semi-diameter to be added	0	16	22
Gives the true height of the Sun's upper Limb	1	49	29
But the same height was by Observation	2	9	32
Whence the Refraction at the apparent height of 2°. $9\frac{1}{2}'$ . .	0	20	3

VI.

WE have here chose the least Altitudes of the Sun, to calculate the Refractions and compare them with those at *Paris* for the

the ſame Altitudes, according to Meſſ[rs] *Caſſini* and *de la Hire*; and do not find thoſe of *Torneå* ſo much different as to infer an Inequality of Refraction at *Torneå*, and at *Paris*.

AND if the Refractions are very much leſs at the Equator than at *Paris*, we may at leaſt be very ſure that their Increaſe from *Paris* to the *Polar Circle* is very inconſiderable; contrary to what has been hitherto thought, that they were twice as great at *Torneå* as at *Paris*.

CHAP. V.

Determination of the Refractions upon Kittis *by* Venus Inoccidua.

I.

WE have farther, upon this Subject, ſome ſingular enough Obſervations upon the Planet *Venus*, which for two Months together appeared always above our Horizon. We obſerved her firſt at *Kittis* with the Quadrant of 3 f. Radius, well verified.

Meridian Altitudes of Venus *upon* Kittis.

To the North.	° ′ ″	Corrected by the Parallax. ° ′ ″
5th *April* 1737, in the Morn.	0 58 6	0 58 21
6th	1 11 44	1 11 59
7th	1 25 5	1 25 20

To the South.		Corrected by the Refraction and Parallax.
6th *April* 1737, in the Even.	47 17 54	47 17 3
7th	47 32 45	47 31 54
Diurnal Motion in Declination		14 51

WE

WE corrected the Altitudes of *Venus*, that were obſerved to the South, by both Refraction and Parallax, putting 15″ for her horizontal Parallax in the diſtance ſhe then was from the Earth.

II.

Calculation of the Refractions upon Kittis, *from the Obſervations of* Venus.

Height of the Pole upon *Kittis* (p. 179.)	66°	48′	20″
Elevation of the Equator . .	23	11	40
Meridian Altitude of *Venus*, the 6th of *April* in the Evening . .	47	17	3
North Declination of *Venus* . .	24	5	23
Diſtance of *Venus* from the Pole, the 6th of *April* in the Evening	65	54	37
Meridian Altitude of *Venus*, the 7th of *April* in the Evening . .	47	31	54
North Declination of *Venus* . .	24	20	14
Diſtance of *Venus* from the Pole, 7th *April* in the Evening . . .	65	39	46
Whence the Diſtance of *Venus* from the Pole, when ſhe paſt the Meridian to the North, on the			

7th

	°	′	″
7th of *April* in the Morning, was	65	47	11½
And consequently her true Altitude	1	1	8½
The Meridian Altitude of *Venus*, the 7th of *April* in the Morning, as observed and corrected by the Parallax, was . . .	1	25	20
Whence the Refraction at the Altitude 1° 25′ is		24	11½

CHAP. VI.

The like Operations at Torneå.

I.

WE continued at *Torneå* our Observations of this Planet, having for that purpose verified the Quadrant of 2 foot.

Meridian Altitudes of Venus.

To the South.	° ′ ″	*Corrected by the Refraction and Parallax.* ° ′ ″
28th *April* 1737, in the Even.	51 36 3	51 35 20
29th	51 38 50	51 38 7
30th	51 41 47	51 41 4

To

To the North.		*Corrected by the Parallax.*
	° ′ ″	° ′ ″
30th of *April* . . .	3 34 58	3 35 14
1st of *May* . . .	3 38 5	3 38 21

II.

Calculation of the Refractions at Torneå, *by the Observations of* Venus.

	° ′ ″
Elevation of the Equator at *Torneå*	24 9 10
Meridian Altitude of ♀ the 28th of *April*	51 35 20
North Declination of ♀ . .	27 26 10
Distance of ♀ from the Pole, 28th of *April* . . .	62 33 50
Meridian Altitude of ♀, the 29th of *April*	51 38 7
North Declination of ♀ . .	27 28 57
Distance of ♀ from the Pole . .	62 31 3
Diurnal Motion in Declination, from the 28th to 29th *April* . .	0 2 47
Meridian Altitude of ♀, the 30th of *April*	51 41 4
North Decl. of ♀	27 31 54
Distance of ♀ from the Pole ,	62 28 6

	° ′ ″
Diurnal Motion of Declination, from the 29th to 30th *April* . .	0 2 57
The Mean of these diurnal Motions	0 2 52
Whereof one half for 12 hours is	0 1 26
Distance of *Venus* from the Pole, the 30th of *April, P. M.* . .	62 28 6
Whence the Distance of *Venus* from the Pole, when she past the Meridian, the 30th of *April* in the Morning	62 29 32
and on the 1st of *May* in the Morning	62 26 40
Whence her true Height { 30th *April, A. M.*	3 21 18
Whence her true Height { 1st of *May, A. M.*	3 24 10
Merid. Alt. of ♀, as observed and corrected by the Parallax. { 30th *April, A. M.*	3 35 14
Merid. Alt. of ♀, as observed and corrected by the Parallax. { 1st of *May, A. M.*	3 38 21
Whence the Refract. at the Altitude . . { 3° 35′ . . .	0 13 56
Whence the Refract. at the Altitude . . { 3 38 . . .	0 14 11

CHAP.

CHAP. VII.

Concerning the Longitude of Torneå.

I.

WE could make no uſe of *Jupiter's Satellites*, becauſe at the time we might have obſerved him, he was too near the Horizon, and always hid in Vapour.

WE endeavoured therefore to determine this Longitude by ſome other Obſervations; from which, as here ſet down, it may be found out, provided correſpondent Obſervations have been made in any Place, whoſe Longitude is known.

Eclipſes of fix'd Stars, by the Moon.

The 12th of December, 1736, P. M.

Time by the Clock.

h	′	″		
11	15	4	*Aldebaran*	Tranſits obſerved with the Teleſcope moveable on an Axis, in the Plane of the Meridian.
11	56	2	*Rigel* . . .	

11 46 $12\frac{1}{2}$ an Occultation of the Star

O

Star μ in the *Linum* of *Pisces*, which gives $11^h 29' 58''$ *true Time.*

AS the Sun rarely appeared, being at Noon less than a Degree above the Horizon, we calculated the Hour by comparing his *Right Ascension* with that of the Stars *Aldebaran* and *Rigel.*

The 12th of January, 1737, P. M.

True Time.

$6^h\ 4'\ 30''$ an Occultation of γ of *Taurus.*
10 57 58 an Occultation of the Northermost of the two Stars of *Taurus*, called ϑ.

The 13th of January, 1737, A. M.

$3^h\ 14'\ 20''$ an Emersion of *Aldebaran.*

WE found the Hour by Observations of the Sun in the Meridian, taken the 12th and 13th of *January.*

The 11th of March, 1737, P. M.

True Time.
$7^h\ 35'\ 9''$ an Occultation of λ in *Gemini.*

II.

II.

A Horizontal Eclipſe of the Moon.

The 16*th of* March, 1737, P. M.

True Time.	Quantity of the Eclipſe.
6h 23′ 55″	5 dig. 0′
25 30	*Promontorium acutum* is diſcover'd.
28 0	4 56
28 30	The Shadow touches the *Mare humorum.*
35 0	4 0
39 30	3 29
40 20	The Shadow touches *Langrenus.*
43 40	*Tycho* half diſcovered.
47 0	*Mare Nectaris* out of the Shadow.
47 30	2 37
49 15	2 21
51 45	2 7
53 35	1 56
7 2 10	End of the Eclipſe, with a Teleſcope of 7 foot.
2 35	End of the Eclipſe, with 2 Reflecting Teleſcopes of 15 Inches.
2 50	

III.

WE have one Obſervation more of a Star eclipſed by the *Moon,* taken upon one of our Mountains.

The 2d of August, 1736, A. M. *upon* Pullingi.

A little before the Obſervation, we compared two exceeding good Watches.

$5^h 36' \ 0''\frac{1}{2}$ by the Watch *R*
$5 \ 26 \ 15$ by the Watch *G* } diff. $9' 44''\frac{1}{2}$

At $5^h 46' 42''$ on the Watch *R*, an Immerſion of *Aldebaran*, in the enlightned Diſk of the Moon.

The Watches compared.	5^h	$49'$	$0''$	*R* } differ. . . $9' 45''$
	5	39	15	*G*

Heights of the upper Limb of the Sun in the Eaſt, with the Quadrant of 2 *foot.*

R...	5^h	$59'$	$14''$	} . . . . $16° 20' 0$
G...	5	49	22	
R...	6	4	$16\frac{1}{2}$	} 16 50 0
G...	5	54	$30\frac{1}{2}$	
R...	6	9	20	} 17 20 0
G...	5	59	32	

Meridian Altitudes of the upper Limb of the Sun.

The 1ſt of *Auguſt* . . . . $41° 35' 10''$

2d 41 20 0

FROM

FROM theſe Obſervations we concluded, that the Immerſion of *Aldebaran* happened at $5^h\ 45'\ 0''$, true Time.

To find the Longitude of *Torneå*, you may likewiſe make uſe of the Obſervations of the Sun at the Equinox, (p. 181.) We have in our Calculations put it at $1^h\ 23'$ Eaſt of *Paris*. It may be more accurately fixt when the correſpondent Obſervations are got, and all of them compared together.

CHAP. VIII.

The Declination of the Magnetic Needle.

THIS Obſervation we made with a Braſs Compaſs, 10 Inches in diameter, by looking through its Sights at an Object placed in the Meridian Line of our little Obſervatory upon the River. And the Mean of our Obſervations with four different

Needles, gave us for the Declination at *Torneå* in the Year 1737, 5° 5′ Weſt.

Mr. *Bilberg*, in 1695, had found it 7°, Weſt likewiſe.

BOOK III.

The Measure of Gravitation at the Polar Circle.

CHAP. I.

Of Gravitation in general.

WHATEVER be the Cauſe of *Gravitation*, we may conceive it as a Force inherent in Bodies, whereby they are animated, as it were, and urged to fall towards the Earth; and upon comparing the Effects of this Force, when it makes a Stone fall to the ground, with what it muſt be to keep the Moon in her Orbit, we ſhall find by Calculation, that the Gravitation which acts here upon the Earth, extends to the Region of the Moon, and regulates her Motion. As the Power which makes Bodies fall downwards, likewiſe retains the Moon in

her Orbit, as ſhe circles round the Earth; we are led by Analogy to think, that every Planet, and the Sun himſelf, has each its Gravitation, producing the like effects: and that what the Moon is to the Earth, that is the Earth it ſelf, and every other Planet, to the Sun. A Gravitation towards the Sun may poſſibly be the Power that keeps them in their Orbits. And indeed the Motion of the heavenly Bodies perfectly correſponds to this univerſal Law. Such are the Effects of Gravitation in the Heavens.

IT would be going too far to mention all its Effects here on Earth. It is This that preſides almoſt in every Phyſical Operation; and while the greateſt part of Machines are contrived to overcome it, it is the Agent that gives motion to the reſt.

IF we are ignorant of the Cauſe of *Gravitation*, as probably we muſt ever be; we know however one of its moſt eſſential Properties; that it is diffuſed through all Bodies in proportion to their quantities of Matter; each Particle of the Body ſharing an equal portion of whatever Cauſe it is that makes it fall.

HERE

HERE we muſt carefully diſtinguiſh between the *Gravitation* of a Body, and its *Weight*. *Gravitation* is that Force, conceived as diſtinct from the Body, which animates and urges every one of its parts to fall; whence it happens, that, abſtracting from the reſiſtance which the Air makes to falling Bodies, a great Body falls juſt as ſoon, and no ſooner, than the ſmalleſt of its parts, if it were detach'd from it, and fell alone from the ſame height.

GRAVITATION in a great Body is no greater than in a ſmall. The Caſe is different as to Weight; *that* depends not only upon *Gravitation*, but likewiſe upon the quantity of Matter of the Body. The *Weight* increaſes in proportion to the Body; it is the product of the Gravitation and the quantity of Matter.

BUT is *Gravitation* the ſame all the Earth over? Will it every where make Bodies fall from the ſame height in the ſame time? A very little attention ſerves to ſhew, that this Queſtion is not to be reſolved by weighing one and the ſame Body in different places.

In

In the place you carry it to, Gravitation will equally affect the Body it ſelf and the Weights you compare it with: And that which weighed a Pound at *Paris*, will weigh the ſame any where elſe.

BUT a Pendulum that ſwings freely, whether ſuſpended by a Thread, or by an inflexible Rod, moves with a determinate Velocity which depends on the length of the Pendulum, and the Force of Gravitation together. And if trial is made with ſuch a Pendulum, keeping its length exactly the ſame in the different places, there can no difference happen in the velocity of its Vibrations, but from a difference of Gravitation. For the different Denſity or Elaſticity of the Air will here produce no ſenſible effect; eſpecially if the degree of Heat in the Countries where the Experiments are made is the ſame, which is exactly enough known by a Thermometer. If, in the Country where the Pendulum ſhould be carried, the Gravitation ſhould be greater, its Vibrations would be quicker; and if it was leſs, they would be more ſlow. This laſt is that Phenomenon which was firſt taken notice of by Mr. *Richer*, in the Iſland of *Cayenne*; and one

one of the nobleſt Diſcoveries in Natural Philoſophy it is. Bodies were found to weigh leſs at *Cayenne* than at *Paris*; and ſoon after a very probable Cauſe of this Phenomenon was aſſigned.

ALL Bodies that have a circular Motion make a continual Effort to recede from the Center. This Effort ariſes from a certain Force there is in Matter, whereby it endeavours to continue in its preſent State, whether of Reſt or Motion. Now as a Body revolving in a Circle deſcribes in every Inſtant a Particle of the Circumference, which may be conſidered as a Right Line, it muſt in every Inſtant be making an effort to go on in the direction of that Right Line; and from this Effort is produced what is called the Body's *Centrifugal Force.*

IF the Earth then revolves about its Axis, each of its Parts endeavours to recede from its Centre of Motion; and the greater the Circle is which the Part deſcribes, that is, the nearer it is to the Equator, the greater will this Effort be; and as it tends to throw off Bodies from the Earth, that is, as its Direction is oppoſite to that of Gravitation, it muſt

deſtroy

deſtroy ſome part of it; and ſo much the more, as the Body is near the Equator. If therefore the *Primitive Gravitation*, which I ſhall call *Gravity*, to diſtinguiſh it from Gravitation as diminiſhed by the Centrifugal Force; if, I ſay, Gravity were abſolutely equal every where, yet the actual Gravitation of a Body muſt be leſs towards the Equator, and increaſe towards the Poles; where at laſt it ſuffers no more any diminution from the Centrifugal Force, becauſe the Poles are no wiſe affected by the Earth's Revolution round its Axis.

THIS Theory of Gravitation is extremely probable, and has been confirmed by all the Experiments that have been made near the Equator.

YET, before our Journey to the North, it was not perhaps abſolutely ſure that Gravitation was thus regularly diminiſhed in going towards the Equator, although the Obſervations made in *America* all gave ſome diminution. The phyſical Cauſe of Gravitation being unknown, it might ſtill be doubted whether the diminution obſerved was owing to the primitive Gravity its being

im-

impaired by the Centrifugal Force, or whether it might not have ſome particular Cauſe combined with the Centrifugal Force: it might even be queſtioned whether the primitive Gravity itſelf was not ſubject to regular, or perhaps irregular Variations. The rather, that ſome Experiments made by able enough Artiſts, ſeemed to give colour to theſe Suſpicions. Mr. *Picard* had not found his Second-Pendulum longer in *Denmark* than at *Paris*, nor even longer than in the Southermoſt Parts of *France*.

IN ſhort, hitherto the only Proof of this Diminution was from Experiments made, towards the Equator indeed, but in places too little diſtant from each other to found an unexceptionable Proof.

IT were to be wiſhed that trial were made in the *Eaſt-Indies*, at the Latitudes of *Cayenne*, *S. Domingo*, and *Jamaica*, whether the diminution was there the ſame as in *America*. But nothing could be more proper for the deciſion of this important Point, and for Natural Philoſophy in general, than the obſerving the Gravitation of Bodies in the moſt Northern Countries, eſpecially after

the

the Doubts that M. *Picard*'s Experiments in *Denmark* had raiſed.

LET it ſtill be remembred what diſtinction I make between *Gravity* and *Gravitation*. *Gravity* is that Force whereby a Body would fall to the Earth, ſuppoſed at reſt: *Gravitation* is the ſame Force, but diminiſhed by the *Centrifugal*. 'Tis only this laſt, diminiſhed, and confounded with the Centrifugal, which we can meaſure by our Experiments; but if we are well acquainted with it, we may come at laſt to diſtinguiſh what of the Primitive Gravity remains, and what has been deſtroyed by the Centrifugal Force.

HITHERTO this Subject has been enquired into with no other view than to determine the Figure of the Earth from the Equilibration of its parts. But the Theory of Gravity ſerves to much greater purpoſes than this Determination.

IF the Primitive Gravity were known, it would not only determine the Figure of the Earth, but demonſtrate its Motion round its Axis.

ON

ON the other hand, if we take the Motion of the Earth for granted, as I believe there is at preſent no Philoſopher that calls it in queſtion; and if its Figure is otherwiſe known, the different Gravitations will diſcover the quantity of primitive Gravity in the reſpective Places.

HENCE likewiſe it may be diſcovered whether, notwithſtanding the differences obſerved in Gravitation, the primitive Gravity be every where the ſame and tends to a Centre, as Mr. *Huygens* ſuppoſed; or if it is different in different Places, and depends upon the mutual Attraction of the parts of Matter, according to Sir *Iſaac Newton*; whether it varies according to any other Law, and to what points it tends. In fine, the Knowledge of Gravitation towards the Earth, may open the way to that of univerſal *Gravity*, the principal Agent in the Machine of the Univerſe.

CHAP.

CHAP. II.

Experiments made at Pello, *upon the Gravitation of Bodies.*

I.

WE had resolved to make our Experiments upon Gravitation as near the Pole as possible; and for that purpose chose *Pello*, whose Latitude is 66° 48′.

THESE Experiments, which elsewhere would be easy enough, were in this Country attended with very great difficulties; and without an extraordinary care to master them, one should find himself very much out in his Reckoning. The great number of Experiments we made, and the great number of Instruments we used, have taught us what close Attention must be had to the smallest Circumstance: and if ever any after us shall undertake such Experiments, and in such a Country, they will be sensible how necessary all our Caution was, and how pertinent

tinent the Account is that I am now to give.

'TWAS theſe ſame Difficulties that hindered Mr. *de la Croyere* to make his Experiments at *Kola* and at *Kilduin*; and forced him to give up the Advantages of this Country, for the Convenience of making them at *Archangel*, farther from the Pole. For us, we were ſo many, and ſo well aſſiſted, that we were able to get over a great many Obſtacles, and to purſue our Reſolution of examining the Gravitation of Bodies in the frigid Zone.

AND it is the ſingular Advantage of theſe Experiments, that they were made nearer the Pole than any ever were, without having at all ſuffered in point of Accuracy, either from the Rigor of the Climate, or any other of the Difficulties we had to ſtruggle with.

II.

THE Inſtrument which we uſed for diſcovering the difference of Gravitation at *Pello* and at *Paris*, is a Clock of a particular Conſtruction, invented by Mr. *Graham*, on purpoſe for ſuch Experiments.

THE Pendulum is composed of a heavy Bob, of the ordinary Lenticular Form, fitted to a flat Brass Rod. This Rod is terminated a-top by a piece of Steel perpendicular to it, whose Extremities are formed into two Edges, that, instead of going between two inclined Planes or two Cylinders, rest upon two flat pieces of Steel, lying both in the same horizontal Plane. The Situation of this Plane is just, when the Extremity of the Rod answers to the Point o of a Limb, in whose Plane the Pendulum moves, and which measures the Arcs described.

THE whole Instrument is inclosed in a very strong Case; and when it is removed, the Pendulum is screwed up by means of a Frame, so as the Steel Edges do not bear on any thing; while the piece of Steel whereof they are formed, is supported on either side of them.

WITHIN the Box, there is applied a piece of Wood hollowed, to receive the Bob of the Pendulum, and so secured by another piece that shuts over it, that neither the Lens nor the Rod can receive any motion. The

only

only liberty the Rod has, is to lengthen and contract itſelf as the Heat or Cold requires; in this reſpect nothing confines it.

THE Lens is 6 inches $10\frac{3}{4}$ lin. in diameter, and its thickneſs at the Centre 2 inches $2\frac{3}{4}$ lin. The Weight that gives motion to the Clock is 11 *lb.* $14\frac{1}{2}$ Ounces, and is wound up once in a Month. And laſt of all, there is fix'd within the Box a Mercurial Thermometer, in which the Point of boiling Water is marked 0, and the Numbers of the Diviſions increaſe with the Cold. Mr. *Graham* ſent us, with this Inſtrument, an Account of the Experiments he had made with it at *London*; wherein he tells us, that when the Thermometer was at 138, the Clock gained upon the *Mean Time* $4' \, 4''$ in a Day; that when it was at 127, it gained $3' \, 58''$. And thus a difference of 11 Diviſions in the Thermometer produced the difference of $6''$, in the Motion of the Clock.

WITH the ordinary Weight, it deſcribed Arcs of $4^{\circ} \, 20'$; with half that Weight it deſcribed Arcs of $3^{\circ} \, 0'$; and theſe great Differences in the Weight and Arcs produced in the going of the Clock,

only a Difference of $3''\frac{1}{2}$ or $4''$ in a day. But ſo much faſter did the Clock go when the ſmaller Arcs were deſcribed.

ONE may ſee from this how little this Clock will be affected by ſmall Differences in the Weights or Arcs, and conſequently by the different Tenacity of the Oil; and how far one may be aſſured, that its Acceleration from one Place to another is the Effect either of an Increaſe of Gravitation, or of the Cold ſhortening the Rod of the Pendulum.

III.

PELLO is a Village of *Finlanders*, as you go up the River of *Torneå*, agreeably enough ſituated upon its Banks. The Art of Maſonry is there abſolutely unknown. Our Lodgings were ſmall Hutts built of Wood, but had nothing of that Solidity which our Experiments required, where there are wanted the very firmeſt Supports.

TOWARDS the end of Summer we had cauſed to be built in one of our Rooms, a great Pillar of hewn Stone; its Thickneſs 6 foot by three; in which we had faſtened ſeveral pieces of Iron to ſupport our Teleſcope

ſcopes and Clocks. To this Wall, which was by this time well dried and ſettled, we fixed a Teleſcope pointed to *Regulus*, very near his Paſſage in the Meridian; and having placed the Clock with all neceſſary Care,

REGULUS paſt by the Vertcial Thread in the Focus.

1737.

The 3d of *April* at	$8^h\ 35'\ 13''\frac{1}{4}$	by the
4th . .	8 36 14	[Clock.
5th . .	8 37 8	

FROM theſe Obſervations, the Pendulum from the 3d to the 4th, had gained upon the Revolution of the fixt Stars $1'\ \frac{3}{4}''$; and from the 4th to the 5th, $54''$.

IV.

WE were ſenſible that this Inequality in the Clock's Motion proceeded from the different degrees of Heat and Cold; and that, though the Room was as cloſely ſhut as it was poſſible in this Country, yet the different Temperature of the Air would de-

ſtroy all Accuracy in our Experiments. Our only reſource was to keep the Clock always in the ſame degree of Heat. This was no eaſy Undertaking in the midſt of a Cold ſo intenſe, and at the ſame time ſo variable; Day and Night we muſt have our Eyes fixed upon the Thermometers, to increaſe the Fire, or let in the external Air. Yet by extraordinary Patience and Attention we overcame all this; kept the Air to a conſtant Temperature, and made the Clock go with as equal a Motion as can be expected in the moſt favourable Climate. The proof of this was the Experiments themſelves, in which the ſmalleſt Neglect muſt have ſhowed itſelf.

V.

ON the 6th we began to regulate the Fire, by means of two Mercurial Thermometers, which we uſed all along in theſe Experiments, both here and at *Paris*. The one made by the Abbé *Nolet*, after Mr. *de Reaumur*'s Standard; the other by Mr. *Prins*. Theſe Thermometers are differently divided; in the Abbé *Nolet*'s the freezing Point is marked 0, and in that of Mr. *Prins* it is marked 32. In either, the Numbers

bers increaſe with the degrees of Heat, and one of the Abbé *Nolet*'s Diviſions is equivalent to very near two of Mr. *Prins*'s. They were placed by the Pendulum, and at the height of the middle of its Rod; and kept continually, for the five days and five nights that theſe Experiments laſted, the Abbé *Nolet*'s between 14 and 15 degrees, and Mr. *Prins*'s between 60 and 62.

IT was of great conſequence that the Thermometers ſhould be placed not only at the ſame diſtance from the Fire as the Pendulum, but likewiſe at the ſame height; for upon lowering them, though at the ſame diſtance from the Fire, the Mercury would fall conſiderably.

THE differences in the length of a Pendulum ariſing from Heat and Cold, are ſo conſiderable with reſpect to thoſe which proceed from the Increaſe of *Gravitation*, that without this Attention to the equal Temperature of the Air, there can never be any tolerable Concluſion drawn from ſuch Experiments.

THE Pendulum describing always Arcs of 4°. 10′. that is, 2°. 5′. on each side of the Limb that measures them, our Observations, after we had regulated the Temperature of the Air, were as follows:

Regulus *passed the Thread of the Telescope.*

1737.	h	′	″
6th of April . . at	8	38	1
7th	8	38	54¼
8th	8	39	48½
9th	8	40	42
10th	8	41	35

FROM these Observations it appears, that from the 6th to the 10th, the Clock had gained 3′. 34″. which gives, for its Acceleration upon one Revolution of the fixt Stars, 53″,5.

CHAP.

CHAP. III.

Obſervations made at Paris *with the ſame Inſtrument.*

AT *Paris*, in the ſame Temperature of the Air, kept up Day and Night by the ſame two Thermometers we had uſed at *Pello*, placed in the ſame manner, the Pendulum ſwinging Arcs of 2°. 10′, on either ſide.

Sirius *paſſed the Thread of the Teleſcope.*

1738.		h	′	″
28th of Febry	. . . . at	8	45	40
3d of March	. .	8	45	24
4th	. . . .	8	45	19
9th	. . .	8	44	49
10th	. . . .	8	44	43
11th	. . . .	8	44	38
12th	. . . .	8	44	32½
13th	. . . .	8	44	27½

WHENCE in 13 Revolutions of the fixt Stars the Pendulum had loſt 1′. 12″,5 which

which gives for one Revolution a Retardation of 5″,6.

CHAP. IV.

Accelerations of the Clock.

I.

Acceleration between Paris *and* Pello.

WE have found (*p.* 216.) that at *Pello*, in one Revolution of the fixt Stars, the Clock gained upon their Motion 53″,5
and that at *Paris* it loſt 5, 6

Whence from *Paris* to *Pello* the Acceleration is 59, 1

II.

Acceleration of the Clock between Paris *and* London.

Mr. *Graham*, upon whoſe Experiments we reckon no leſs than upon our own, had obſerved at *London*, that when the Thermometer contained in the Caſe of the Clock ſtood at 127, the Clock gained upon the *Mean*

Mean Time 3′, 58″. in a day, that is, 2″,1 upon one Revolution of the fixt Stars. Now this Diviſion 127 of his Thermometer anſwering to 14½ and 61 of theſe two which we uſed both at *Pello* and at *Paris*, it is plain the Experiments at *London* and at *Paris* were made in an Air of the ſame Temperature. The Oſcillations were likewiſe the ſame, *viz.* 2°. 10′. on either ſide of the Perpendicular. Whence the Clock having, at *London*, gain'd upon one Revolution of the fixt Stars . . . . . . 2″,1
and at *Paris* having loſt 5, 6

the Acceleration from *Paris* to *London* in one Revolution, is 7, 7

CHAP. V.

Experiments made with other Inſtruments.

WE had another Inſtrument, excellent for theſe Purpoſes; a Clock of Mr. *Julian le Roy*, which, in all the Trials we made, was found to go admirably well.

ALL

ALL this Country being, as it were, one Maſs of Iron and Loadſtone, we apprehended the effects of ſome Magnetiſm in uſing this Clock, whoſe Rod was of Steel. We likewiſe wanted to make ſome Experiments with Pendulums of different ſpecific Gravities. Mr. *Camus*, who joins to his other Accompliſhments a perfect Skill in Mechanics, ſupplied alone whatever we could want in a Country that knows no other Arts but Fiſhing and Hunting. He formed upon a Turn, five perfect Globes of two Inches $4\frac{1}{2}$ lin. diameter, of as many different Metals which he had melted down. Each Globe was paſt through with a Braſs Rod, which was eaſily fixt to the extremity of another of the ſame Metal; this laſt having been firſt fitted to the Clock.

IT was in the time of our moſt accurate Experiments at *Pello*, the 6, 7, 8, 9 and 10th of *April*, when the Air was kept Night and Day in the ſame degree of Heat, that we made the Compariſon of the two Clocks, Mr. *Graham*'s and Mr. *le Roy*'s. We made this laſt go 12 Hours with each of the five Globes, charging the Weight that gives the

Motion

Motion with as many leaden Bullets as made the Vibrations always of 3°. 55′. on each ſide. A Circumſtance which we likewiſe obſerved at *Paris.*

THE Motion of this Clock, with the five different Globes, at *Pello* and at *Paris*, and in the ſame degree of Heat, was as follows:

In 12 *Hours, by Mr.* Graham's *Clock.*

	At *Pello.*		At *Paris.*	
	′	″	′	″
The Globe of Lead loſt . .	9	$14\frac{2}{3}$	. . 9	14
The Globe of Silver loſt .	8	42	. . 8	44
The Globe of Iron loſt . .	5	29	. . 5	$29\frac{1}{2}$
The Globe of Tin loſt . .	6	6	. . 6	8
The Globe of Copper loſt	6	48	. . 6	50

THE difference of 2″ which three of theſe Globes give between the Motion of the Clock at *Pello* and here, is not conſiderable. It may probably have been occaſioned by the manner in which the Rods of the Globes were fitted to the Clock. If the extremities of the Rods to which the Globes were fixed, miſs'd ever ſo little to riſe to the ſame point of the Rod that was com-

mon

mon to them all, ſome ſmall difference in the lengths muſt happen. And how ſmall indeed is ſufficient to produce a difference of 2″! This, however, muſt always be a Source of ſome little Error in Experiments made with Clocks, whoſe Pendulums are taken off, when they are carried from one place to another.

HENCE we may ſee how proper good Clocks are for diſcovering the Increaſe or Decreaſe of Gravitation. And if it had not been actually verified, no body could ever have believed, that in theſe Experiments two Clocks of ſuch different Conſtruction as Mr. *Graham*'s and Mr. *le Roy*'s are, ſhould ſo accurately correſpond. In Mr. *le Roy*'s, the Rod of the Pendulum was fixt to two Springs, which might be ſuſpected to have different Elaſticities: The Globes differed widely from Mr. *Graham*'s Lens, in Weight as well as Shape; and the Arc which they deſcribed was almoſt double to that of the Lens.

WE ſhall ſay nothing of ſome other Experiments which give the Increaſe of Gravitation at *Pello* ſtill greater than we found

found it by Mr. *Graham* and Mr. *le Roy*'s Clocks, becauſe the Inſtruments with which they were made, are ſo inferior to theſe Clocks that they ought not to be ſo much as compared with them.

CHAP. VI.

Reflections upon the Increaſe of Gravitation.

I.

Compariſon of the Increaſe of Gravitation between Paris *and* Pello, *with the ſame as deduced from Sir* Iſaac Newton'*s Table.*

THE Acceleration from *Paris* to *Pello*, found as above, is greater by 6″,8 than Sir *Iſaac Newton*'s Table makes it, (*lib.* 3. *Phil. Nat. Princ. Math.*) and conſequently, according to his Theory, the Earth is *flatter* than he determines it to be.

II.

Comparison of the Increase of Gravitation between Paris *and* Pello, *with what results from the Experiments made at* Jamaica.

FROM Mr. *Campbell's* Experiments at *Jamaica* made with one of Mr. *Graham's* Clocks, Mr. *Bradley* has calculated another Table, (*Phil. Trans.* *N°*. 432.), upon the Principle employed by Sir *Isaac Newton* and Mr. *Huygens*, that Gravitation increases towards the Pole as the Square of the Sine of the Latitude; and the Acceleration from *Paris* to *Pello*, as deduced from this Table, exceeds what we found it to be, by 4″,5.

III.

Comparison of the Increase of Gravitation with what results from Mr. Huygens's *Theory.*

IN fine, All the Experiments which the Academicians, sent by the KING to *Peru*, have made, either at *S. Domingo* or the *Equator*, conspire with ours, to make the Increase of Gravitation towards the Pole, greater than according to Sir *Isaac Newton's*

Newton's Table, and by conſequence the Earth flatter than he has made it. And all of them fall ſo wide of Mr. *Huygens*'s Theory (*Diſcours de la cauſe de la Peſanteur*) which makes it ſtill leſs, that his Theory muſt itſelf be wide of the Truth.

IV.

Compariſon of the Increaſe of Gravitation between Paris *and* Pello, *with that between* Paris *and* London.

THE Acceleration from *Paris* to *Pello* being 59″,1. that from *Paris* to *London* ought to be 9″,8. and we found it above, to be 7″,7. Whether this difference is real, or if it is owing to ſome Error in our Experiments, I leave others to judge. And if this laſt is the caſe, how exquiſite muſt that Inſtrument be, which, tranſported from *London* to *Pello*, from *Pello* to *Paris*, and tried in theſe three places, is found to agree ſo accurately with itſelf?

V.

Comparison of the Gravitation of Bodies at Paris *to that at* Pello.

THE Gravitation of Bodies at *Paris* is to that at *Pello*, as the Square of the Number of Oscillations of a Pendulum at *Paris* in one Revolution of the fixt Stars, is to the Square of the Number of Oscillations at *Pello* in the same time, that is, as 10000 to 10014.

VI.

Length of the Pendulum that swings Seconds at Pello.

TO find the Length of a Pendulum that swings Seconds at *Pello*, you have only to compare the Squares of the Number of Oscillations made in the same time at *Pello*, and at *Paris*, with the length of a Pendulum at *Pello*, and that of a Pendulum at *Paris*; which last Mr. *de Mairan*, has, by repeated and unquestionable Experiments, found to be 440,57 Lines. And you will find the length of a Second-Pendulum at *Pello* to be 441,17 Lines.

FOLLOWS a *Table*, which I have calculated, upon the Increaſe of Gravitation between *Paris* and *Pello* as above determined; and upon this Principle, That Gravitation increaſes from the Equator to the Pole, very nearly in the Ratio of the Squares of the Sines of Latitude. In this Table, the Augments of Gravitation are expreſſed two different ways; by the *Accelerations* of a Clock in a Revolution of the fixt Stars, and by the *Lengthenings* of a Pendulum that ſwings Seconds from the Equator to the Pole.

TABLE

Of the Accelerations of a CLOCK, and of the Lengthenings of a PENDULUM *from the Equator to the Pole.*

LATITUDE of the Place.	ACCELERATION in one Revolution of the fixt Stars.	FRACTIONS of a Line, and Lines by which the Pendulum is to be lengthened.
0°	0″	0
5	1,6	0,016
10	6,4	0,065
15	14,3	0,145
20	24,9	0,254
25	38,1	0,387
30	53,3	0,542
35	70,2	0,713
40	88,1	0,896
45	106,6	1,084
50	125,1	1,273
55	143,1	1,455
60	159,9	1,626
65	175,1	1,781
70	188,3	1,915
75	198,9	2,023
80	206,8	2,103
85	211,6	2,152
90	213,2	2,169

CHAP. VII.

A Method for finding the Direction of Gravity.

PROBLEM.

The Figure of the Earth being given, as also the Proportion of Gravitation at the Equator to that of any given Latitude; To find the Angle which the Direction of the actual Gravitation makes with the Direction of the primitive Gravity, or that Point of the Earth's Axis to which Gravity tends.

LET the Spheroid $APap$ represent the Earth, whose Axis is Pp, and the Diameter of the Equator Aa. Let the Gravity in A, that is, at the Equator, be represented by AG; and the centrifugal Force by AQ; then will the Gravitation there be represented by AH, the difference of AG and GH (or of AG and AQ.) Fig. 18.

IN

IN any other place of the Earth D, let the Gravitation be expreſs'd by $D T$. And by the Laws of Hydroſtatics, ſeeing the Direction of Gravitation is always perpendicular to the Surface of the Earth, $D T$ will be perpendicular to a Line touching the Spheroid in D.

IF upon $F D$ continued, there be taken $D Z = \frac{D F \times A Q}{A C}$, $D Z$ will repreſent the centrifugal Force in D, and its Direction will be that of $D Z$.

DRAWING then from the Point T, the Lines $T N$, $T S$ perpendicular to the Axis, and forming the Rectangle $D N T S$, the Gravitation will be reſolved into two Forces, one acting in the Direction DS, which is not affected by the centrifugal Force; and the other acting in the Direction DF, which has been diminiſhed by it.

THE centrifugal Force has taken from this laſt the Quantity $D Z = \frac{D F \times A Q}{A C}$,

which

which muſt be reſtored to the Force in the Direction DF, in order to find the whole Force of primitive Gravitation in the Direction DF. Taking therefore $NV = DZ$, and, through V, drawing VO parallel to the Axis, the Lines VO, SO will repreſent the Forces which reſult from Gravity. The Diagonal DO, the quantity of Gravity itſelf, and the little Angle ODT will be that of the two Directions of Gravity and Gravitation.

THE centrifugal Force at the Equator being $\frac{1}{288}$ of the Gravitation, we have $AQ = \frac{1}{288} AH$, and $DZ = \frac{DF \times AH}{288\ AC} = TO$. Having drawn from a Point infinitely near D, the Line dM parallel to DE, and from the Point T, the Line Tt perpendicular to DO, we ſhall have by ſimilar Triangles $Dd : Md :: TO : Tt$, or $Dd : Md :: \frac{DF \times AH}{288\ AC} : Tt = \frac{Md \times DF \times AH}{288 \times Dd \times AC}$, the Sine of the Angle TDO to the Radius DT. Whence we have the Equation $\frac{Tt}{DT} = \frac{Md \times DF \times AH}{288 \times Dd \times AC \times DT}$.

THIS

THIS Formula contains the Angle of the two Directions of Gravity and Gravitation; the Latitude of the Place expreſs'd by $\frac{Md}{Dd}$; the Radius of the Equator, and the Radius of the Parallel under which the Experiments are made; with the Ratio of Gravitation at that Place to Gravitation at the Equator. Whence different Theorems may be deduced, for different Suppoſitions of the known Quantities.

THE END.

W. H. Toms Sculp.

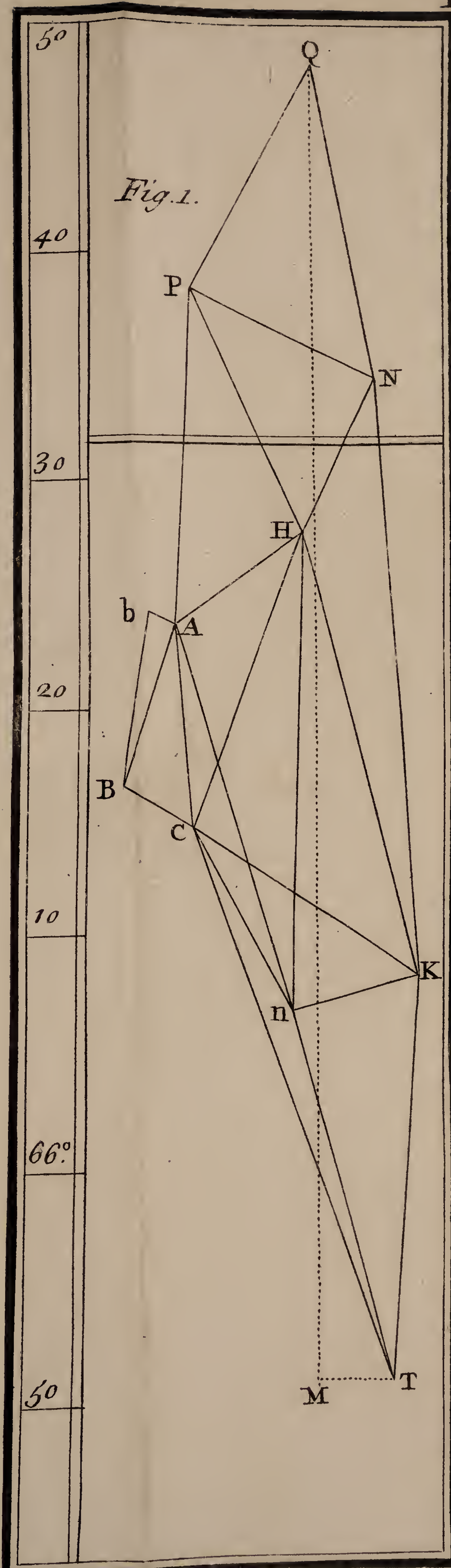


Fig. 1.

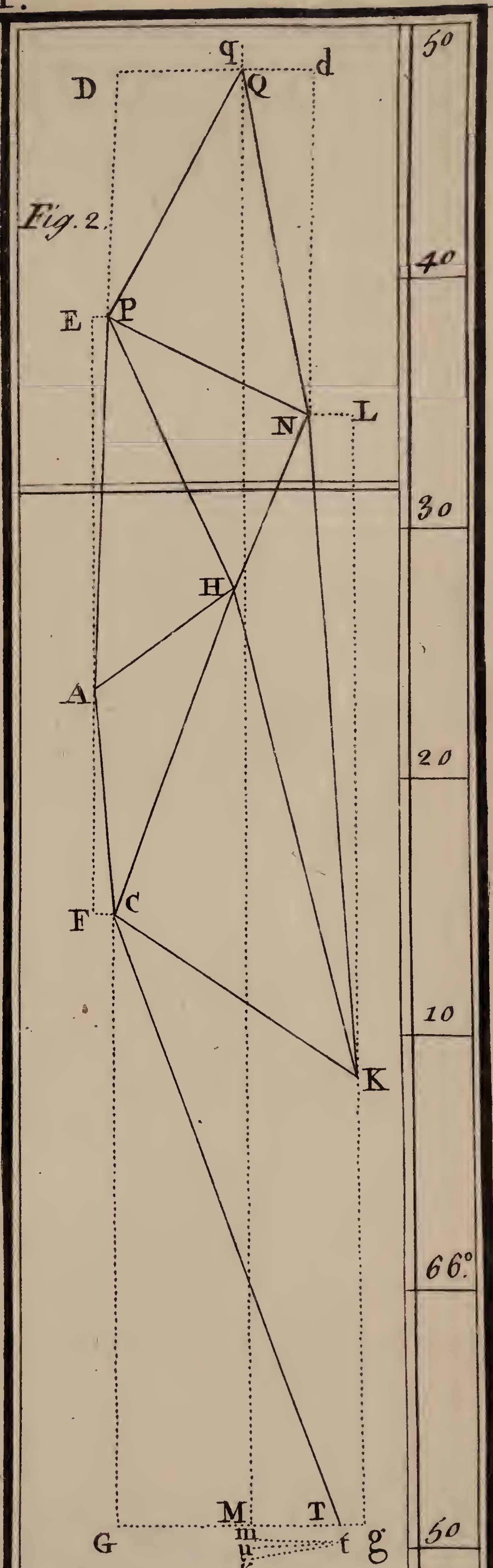


Fig. 2.

$DP + EF + CG = 54940.39.^{t.}$

$dN + Lg = 54944.76.$

at a mean. $QM = 54942.57.$

II.

Fig. 3.

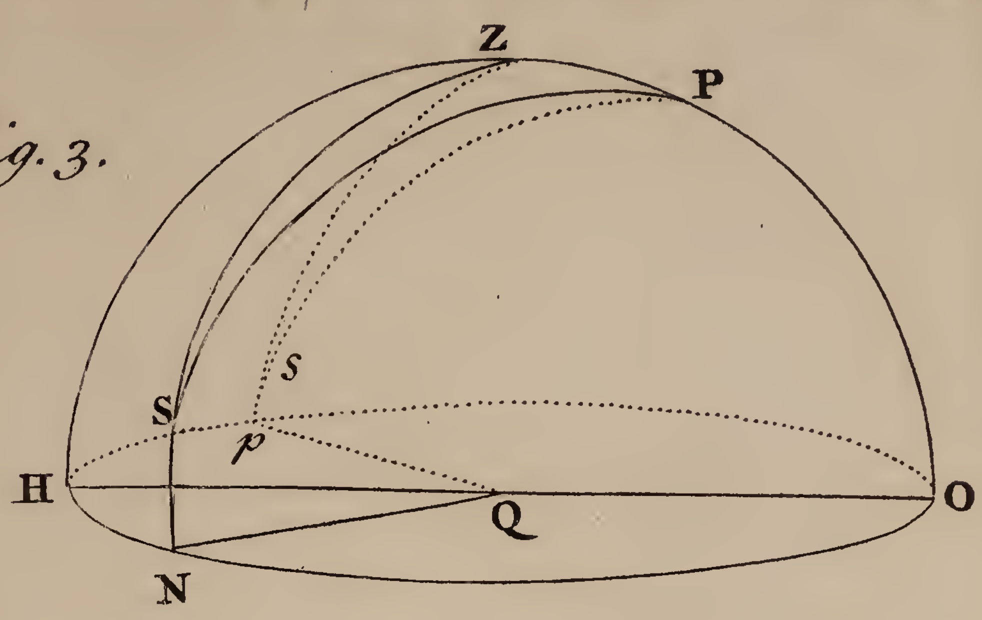


Fig. 4.

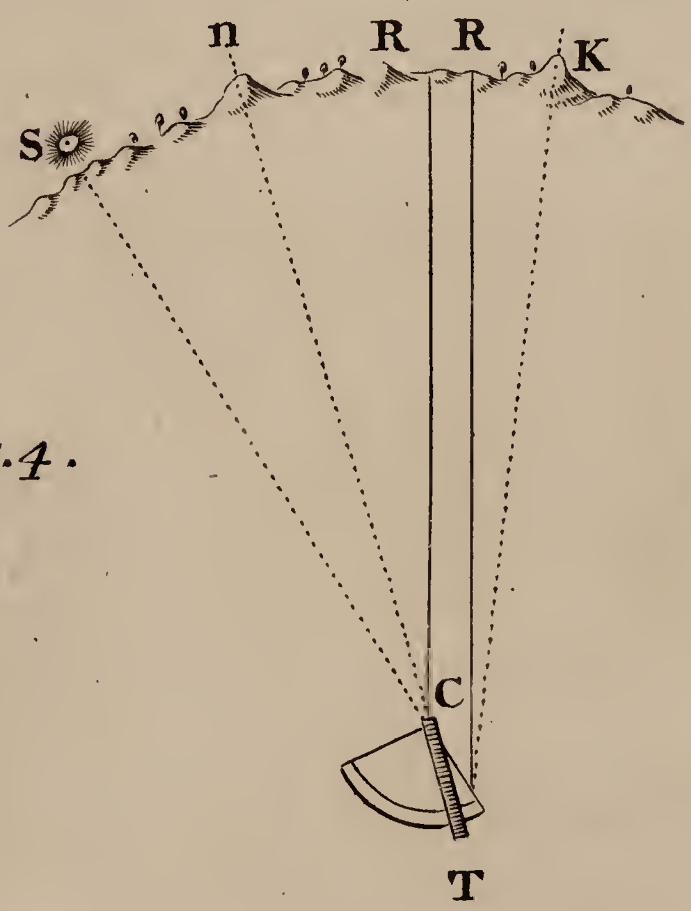
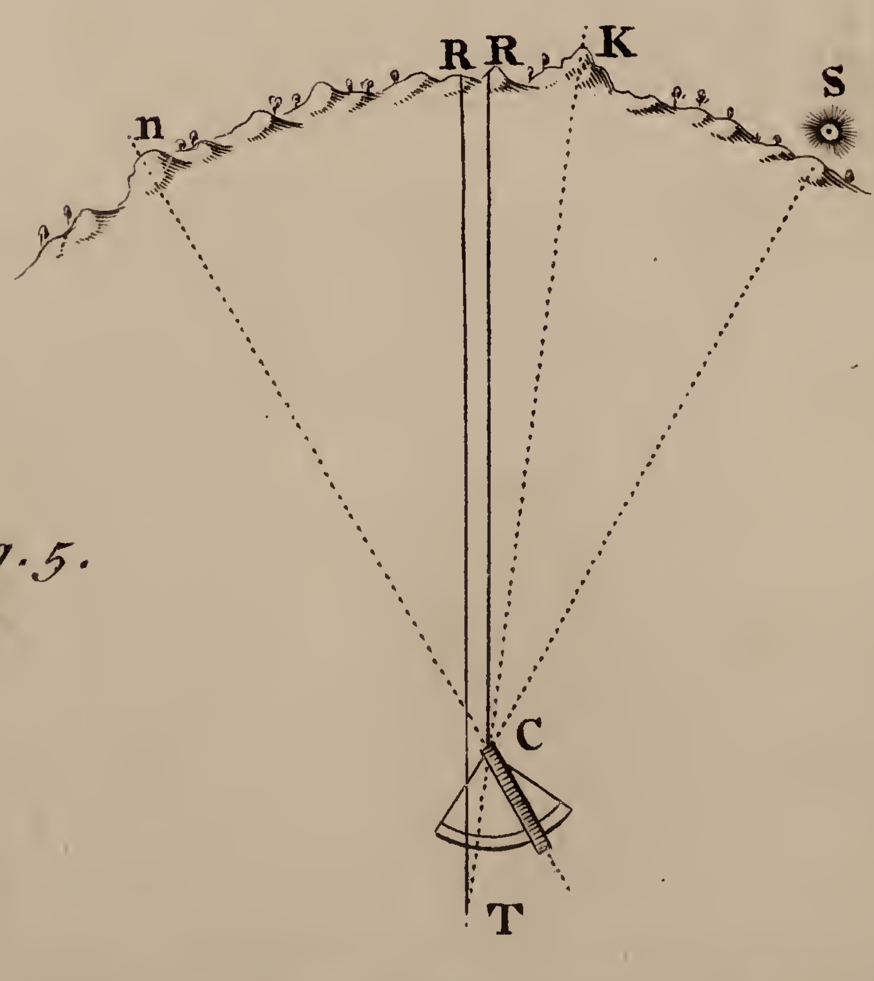


Fig. 5.



III.

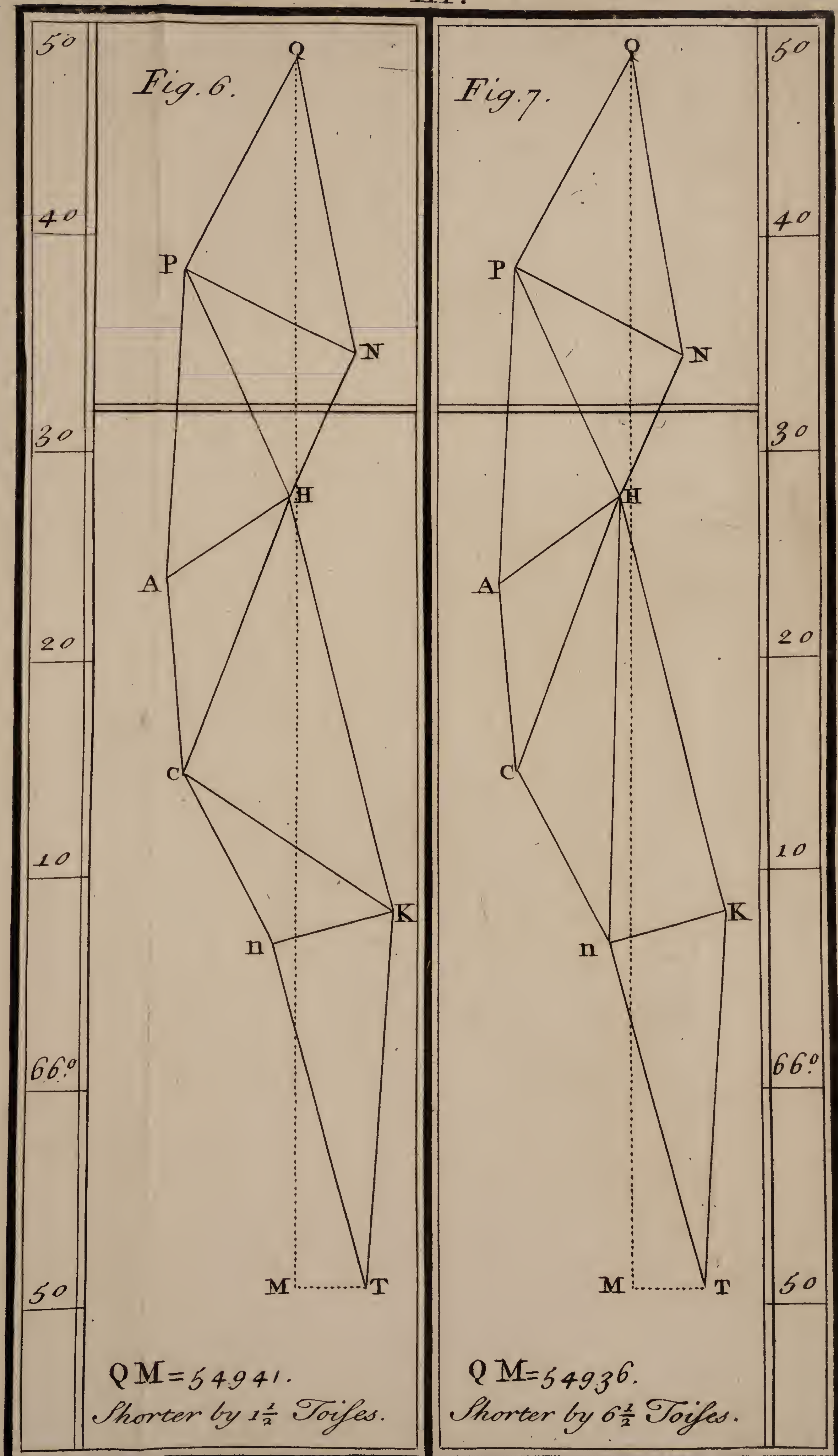


Fig. 6.
Fig. 7.
Q
P
N
H
A
C
K
n
M
T
50
40
30
20
10
66.°
50
QM=54941.
Shorter by 1½ Toises.
QM=54936.
Shorter by 6½ Toises.

IV.

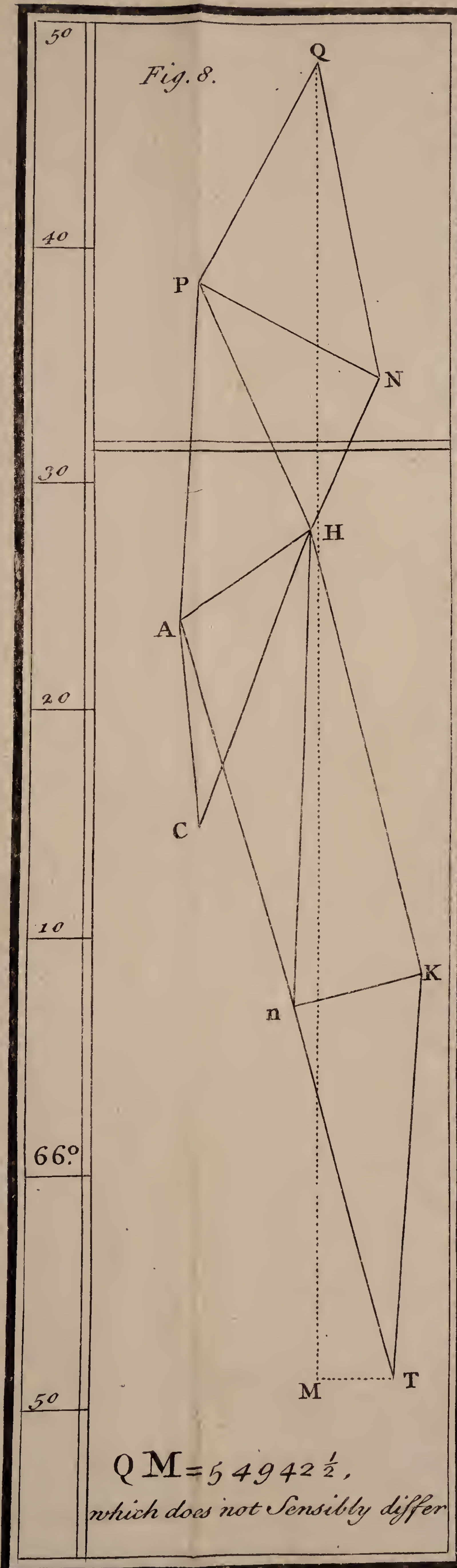


Fig. 8.

Q M = $54942\frac{1}{2}$,
which does not Sensibly differ

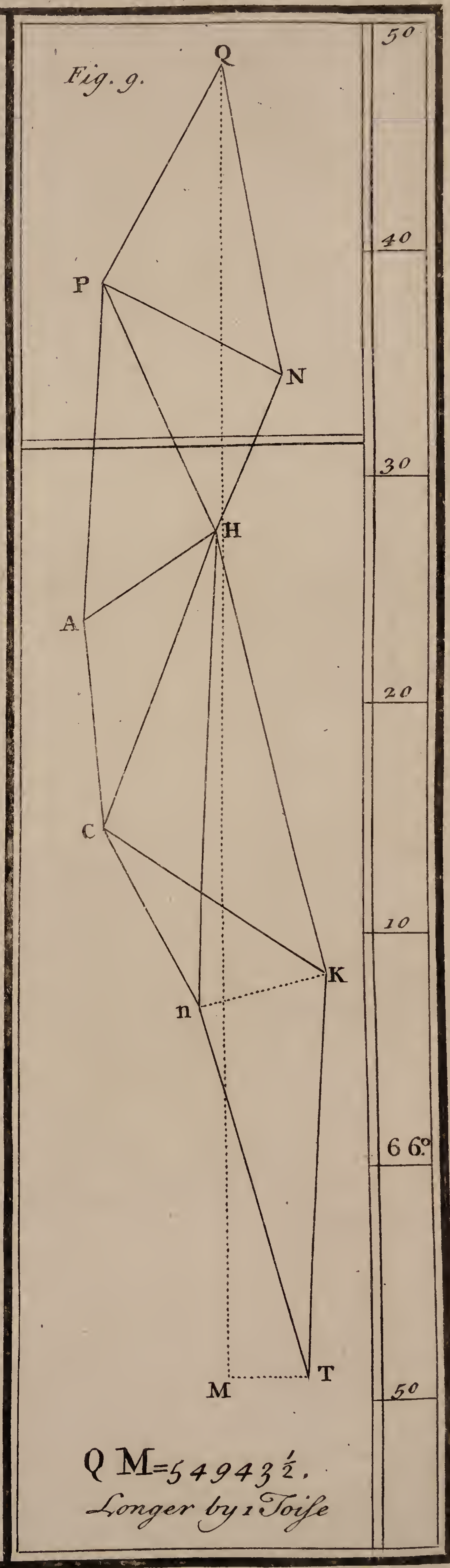
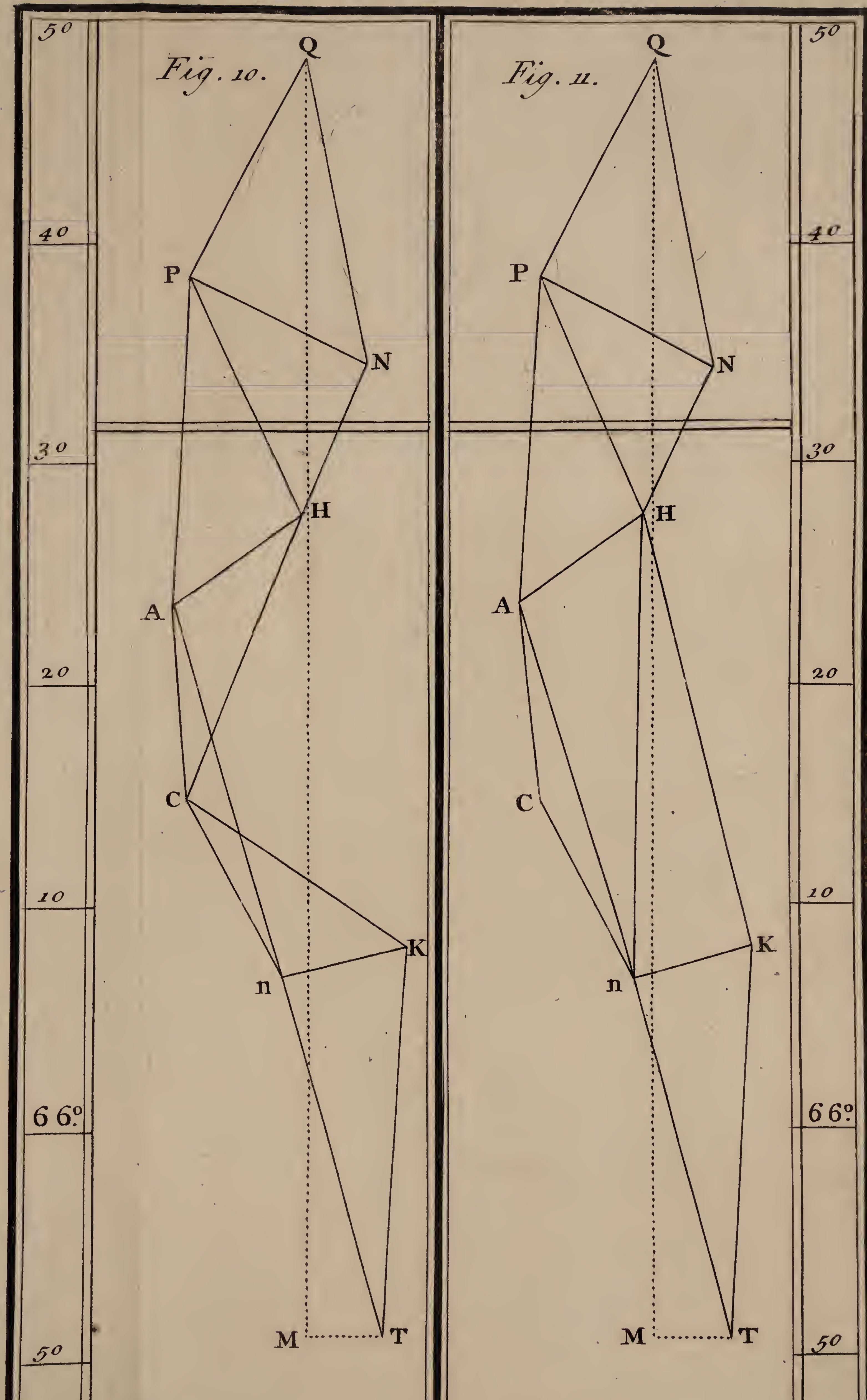


Fig. 9.

Q M = $54943\frac{1}{2}$.
Longer by 1 Toise



Q M=54925, *Shorter by 17½ Toises.*

Q M=54915½, *Shorter by 27 Toises.*

VI.

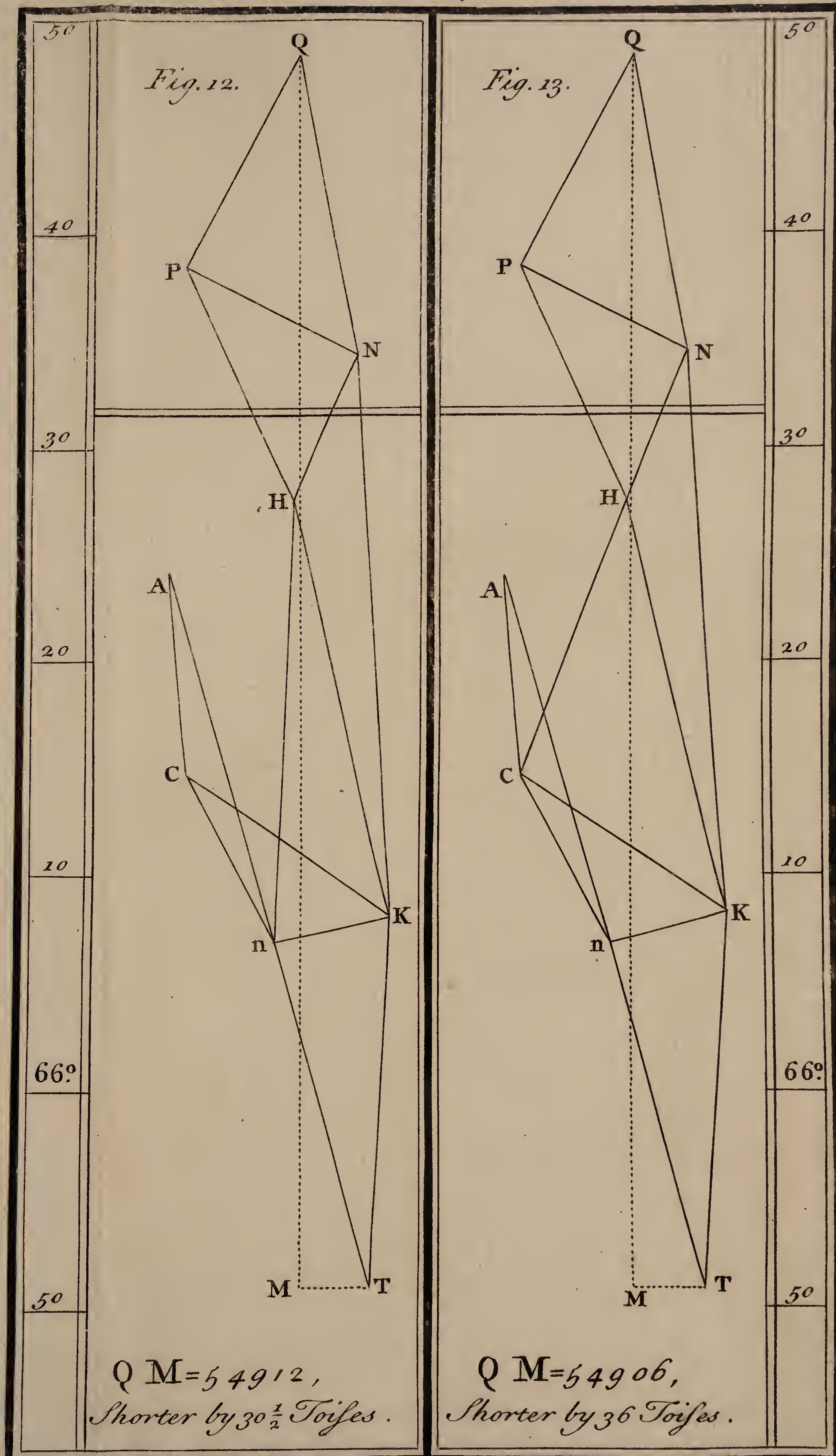


Fig. 12.
Fig. 13.
Q
P
N
H
A
C
K
n
M
T
50
40
30
20
10
66°
50
Q M=54912,
Shorter by 30½ Toises.
Q M=54906,
Shorter by 36 Toises.

VII.

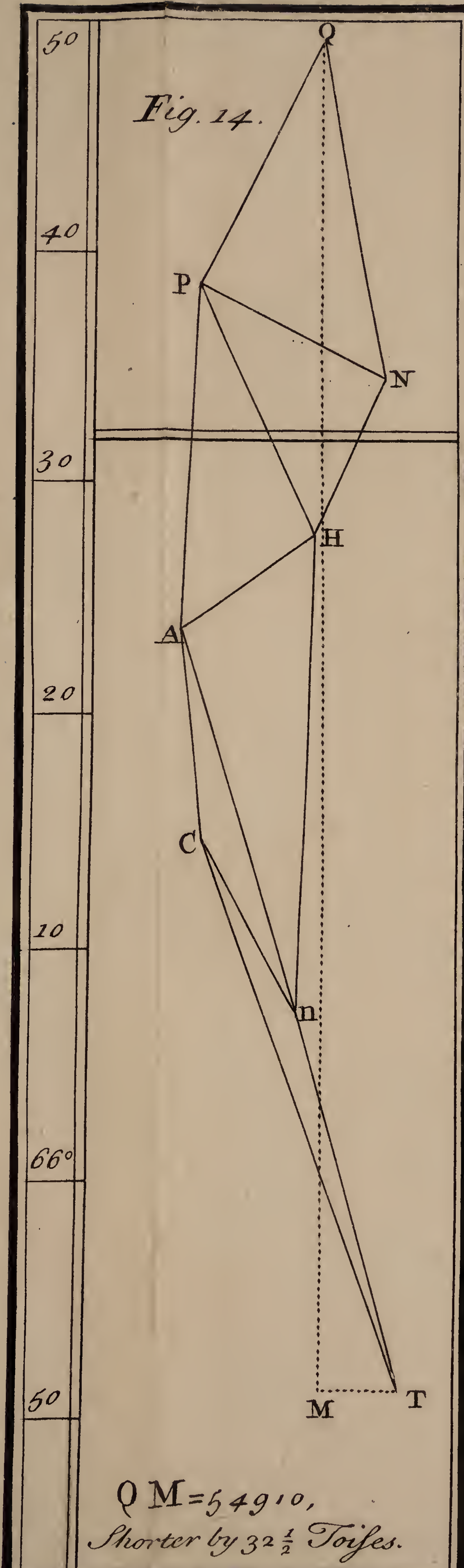


Fig. 14.
Q
P
N
H
A
C
n
M
T
50
40
30
20
10
66°
50
QM=54910,
Shorter by 32½ Toises.

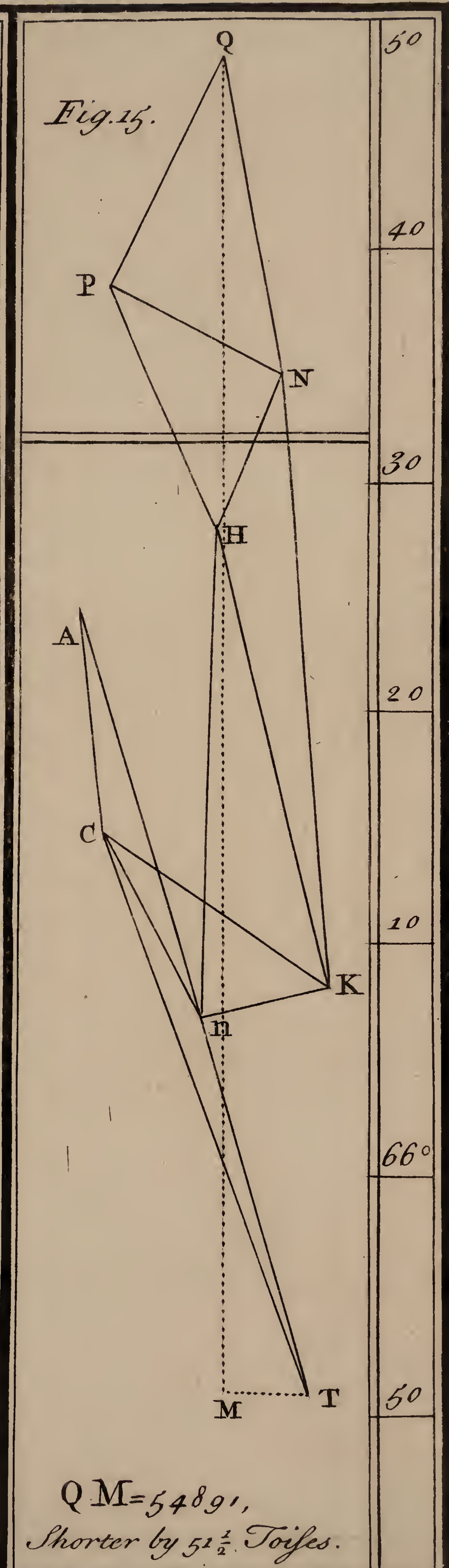
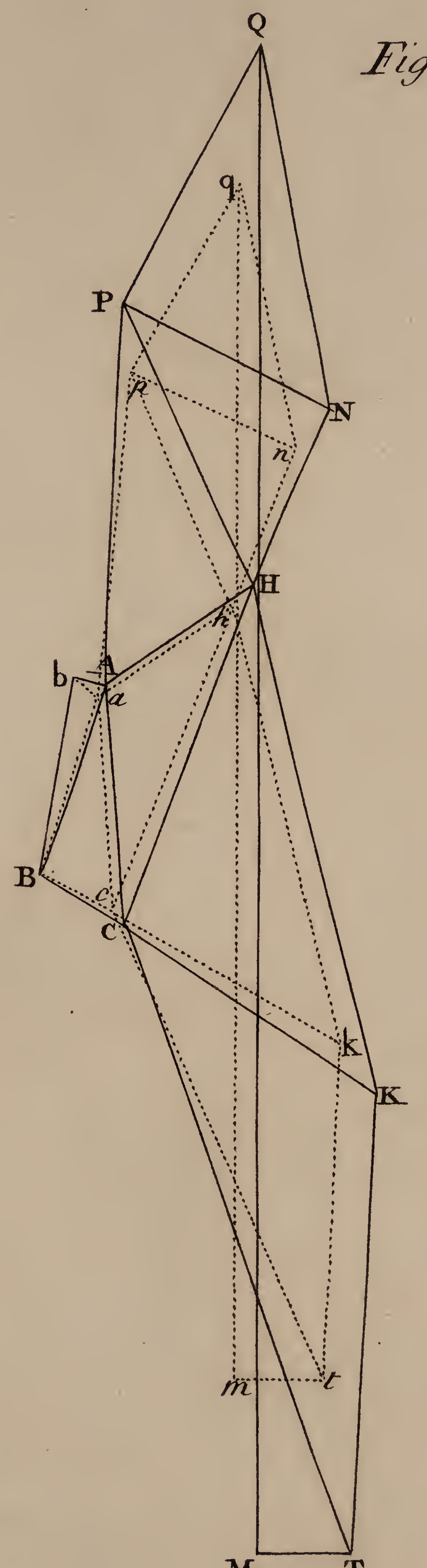


Fig. 15.
Q
P
N
H
A
C
K
n
M
T
50
40
30
20
10
66°
50
QM=54891,
Shorter by 51½ Toises.

VIII.

Fig. 16.



qm = 54886. Toises, Shorter than QM *by 54 Toises.*

IX.

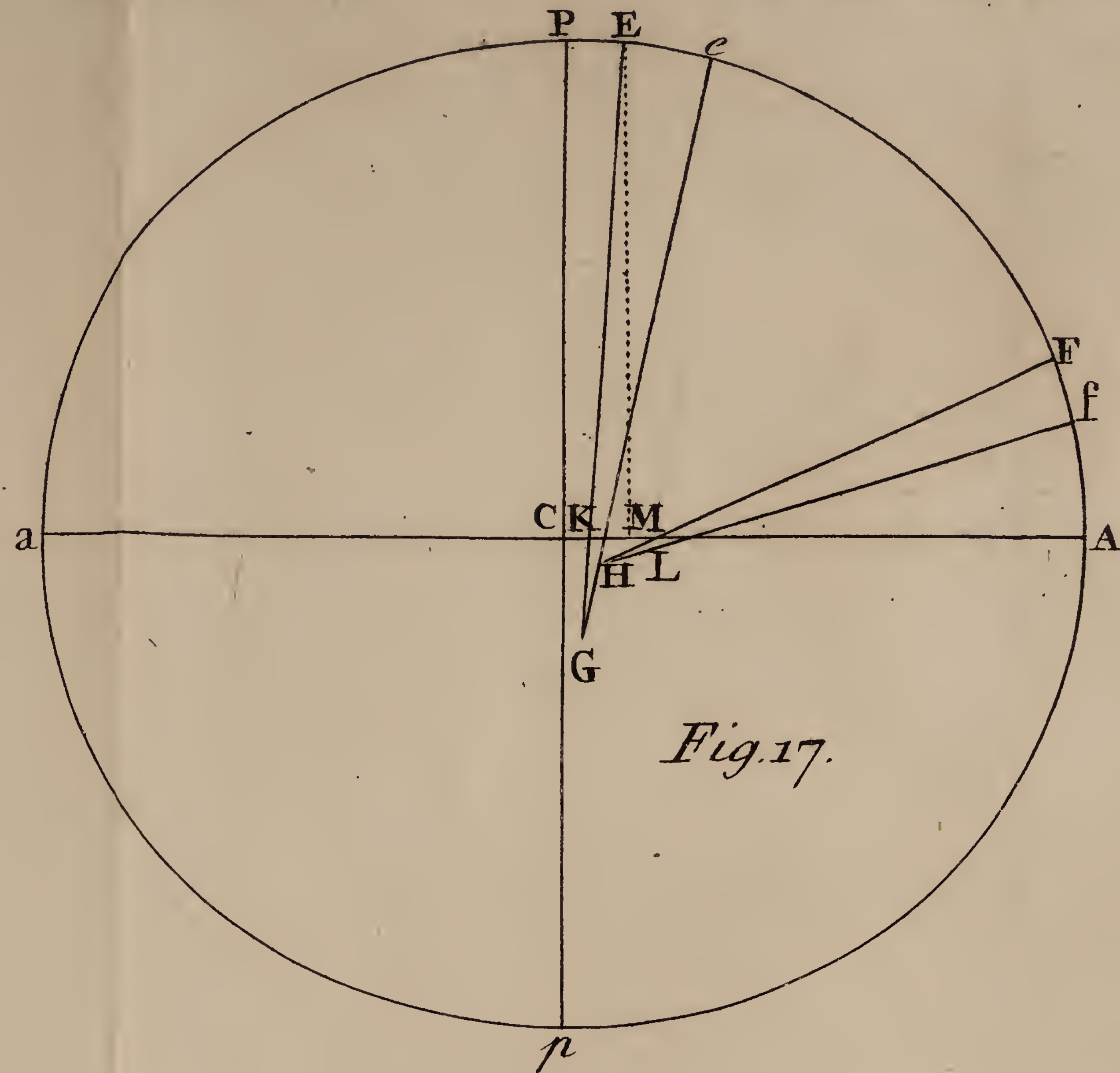


Fig. 17.

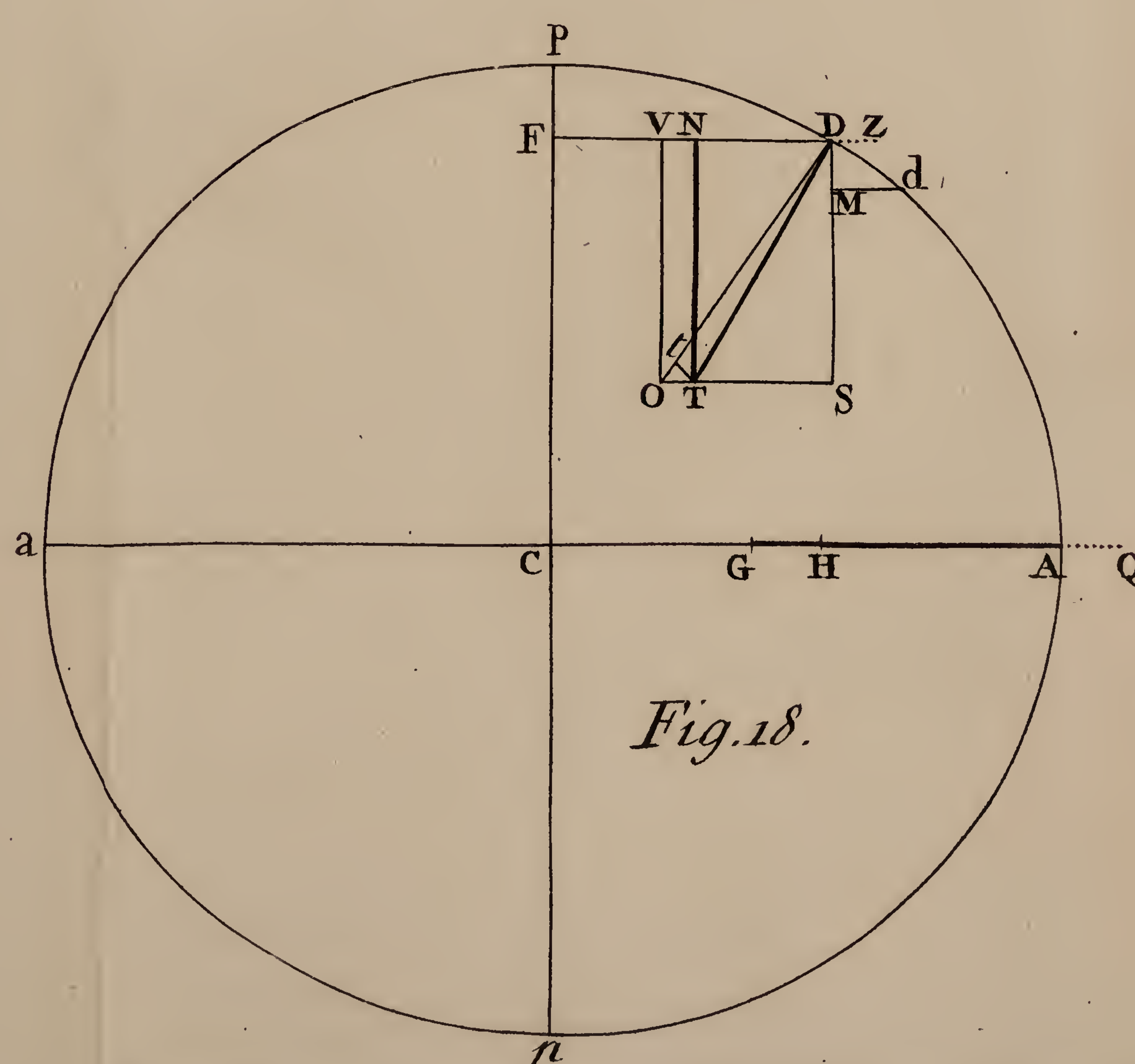


Fig. 18.